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Contents

The Lower Incisors In Theory And Practice

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We orthodontists customarily regard the denture as a whole; we do not confine ourselves to the denture only, but also take into account the entire patient and his constitution. Nevertheless, there sometimes arises the need to concentrate one's attention upon a certain section of the denture. Such a section presents itself today in the lower incisor region. First, because of the fact that there has been a certain eclipse of the six year molar as the "key to occlusion", lower incisors have usurped a kind of "key position" in newer diagnostic procedures. Second, these teeth seem to have also become a problem in therapeutic procedures during the last few years. While in Bogue's and Angle's times widening was the cure-all, today we have quite a range of possibilities. One may be that of resignation, as expressed by Howes: "The patients and their parents are prepared for some irregularities of the mandibular incisors." Another is the outright extraction of two premolars. In between is the extraction of an incisor, stripping and, of course, widening.

Though all this has been treated and discussed repeatedly so that there hardly appears to be any need to go into it once more, it seems to the best of the author's knowledge that the interrelation between diagnostic and therapeutic precedures has not yet been investigated, i.e., the *double personality* of the mandibular incisors as diagnostic subjects on the one hand and as therapeutic objects on the other.

The significance of the lower incisors as therapeutic objects is threefold:

(1) As the first to erupt they may be the first sign of an incipient malocclusion.

(2) They are difficult to treat as they relapse easily.

(3) Crowding of the mandibular incisors is the most frequent anomaly.

In this connection it might be opportune to give a few statistical figures.

Statistics

In Table I the results of some investigations regarding crowding have been collected. They are rather uniform and may be roughly summarized as follows: (1) crowding of lower incisors occurs in about fifty per cent and (2) crowding in the lower jaw is between fifty and one hundred per cent higher than in the upper.

Table I

Frequencies of maxillary and mandibular crowding

	Barrow and White	Huber and Reynolds	Lundström*	Moore	Moorrees* and Reed	Seipel
	Anteriors	Anteriors		Anteriors		
Maxilla	24%	32.2%	35%	26.4%		25%
Mandible	51%	52.6%	50%	48.3%	69%	51%

* Estimate from histo or scattergram respectively

These figures call for some explanation. Generally, disrelations between the widths of the upper anterior teeth and of the lower ones are thought to be the cause. But if this were the only cause, it should work both ways, i.e., leading equally to crowding and spacing. Further, it does not explain the twice as much occurrence of crowding in the mandible. Thus we are led to the conclusion that there exist still other factors responsible for this peculiarity. It seems to the author that we might get a clue from studying phylogenetic development.

Phylogenetics – The Mandible

It goes without saying that though this paper is concerned with the lower incisors, we cannot treat them in a kind of "splendid isolation". There must be considered relations with the other mandibular teeth, with their antagonists and with their very base, the mandible itself, and especially with that part of it which has evoked so much interest among dentists, anatomists, anthropologists and even laymen: the chin.

A few years ago the chin problem was comprehensively treated by DuBrul and Sicher under the rather challenging title *The Adaptive Chin.* After reviewing and rejecting the current theories, especially that of reduction (Weidenreich), they proceed to develop their own theory: the chin is a sort of buttress which has come into existence to reinforce this part of the mandible against the masticatory stresses which converge here and which, after the mandible has undergone phylogenetic changes, make this point a particularly vulnerable one. Thus, the chin has arisen in response to changed conditions and they speak therefore of the "adaptive chin".

The author cannot but look at the problem differently. Siding with the representatives of the reduction

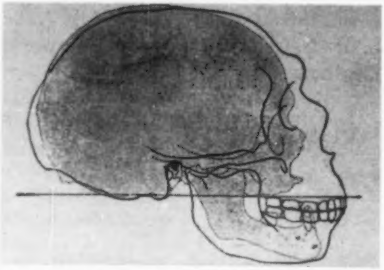


Fig. 1 Modern skull (E.D.Cope) in comparison with Neanderthal (La Chapelle-aux-Saints). After Boule.

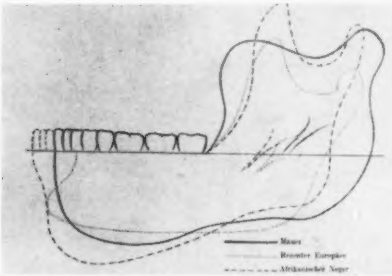
theory, he thinks that not the chin, but the teeth and especially the lower incisors are "adaptive", since it is they which had to adapt themselves to a reduced space. A few illustrations shall elucidate this point. Fig. 1 shows the changes which have taken place in the build of the skull since paleolithic times. Of special interest for us will be the reduction which befell the face and jaws. As we are now mainly concerned with the conditions in the mandible, the next two pictures will give us more details. Fig. 2 is a reproduction of Schoetensack's comparison of three mandibles of which only the Heidelberg jaw and the modern one will concern us here. Fig. 3 is Keith's comparison of the mandible of a Neanderthal child with that of a recent juvenile specimen. If we look at these pictures, we are immediately aware of the fact that a substantial reduction has taken place, but we will not get any hint as to where it has taken place; the superimpositions as they are made here might easily lead to the idea that out of these changes the chin has evolved as something new. If, however, we superimpose the same mandibles as in Figs. 4 and 5, i.e., on a point corresponding approximately to the gnathion, we shall get quite another impression.

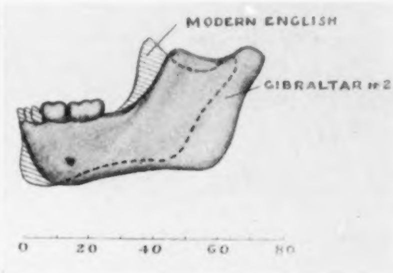
From comparing different growth stages we know the difficulties we have

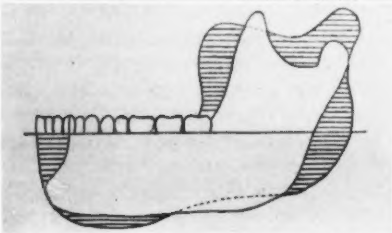
to contend with when we wish to fix growth centers in order to superimpose tracings. In the same way we have, of course, no certainty where to place—if one may say so—the *reduction center.* Superimpositions like those in Figs. 2 and 3 would imply reduction at the distal part of the corpus and ramus and apposition in the front. But, if we superimpose the tracings as in Figs. 4 and 5, we are led to the conclusion that reduction has taken place rather equally in the corpus and the ramus, yet the tooth bearing part has changed drastically in extension as well as in position. Such a process seems to us very probable, as the extremely massive corpus mandibulae should resist radical changes more effectively than the cancellous tooth bearing part.

In addition to this we also have to consider what has been called the *chin of the upper jaw*—the anterior spina nasalis. This process, too, does not exist in apes or early men, and comes into existence simultaneously with the chin. Both these developments we can explain by the same process, namely the reduction of the tooth bearing parts in the upper and lower jaw, a reduction which has not yet enveloped the basal parts in either jaw. For the emergence of the chin, the mandibular prominence, particularities of muscular behavior and masticatory stress have been adduced by DuBrul and Sicher. It should be difficult for them to claim the same causes for the development of the anterior nasal spina.

DuBrul and Sicher try to discredit the reduction theory further by stating that reduction should have acted on both corpus and alveolar process to-







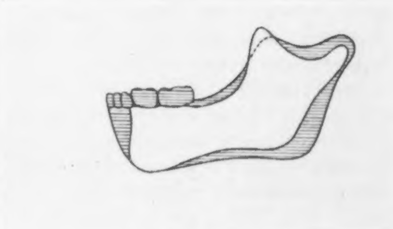


Fig. 2, upper left. Superimposition of mandibular profiles of Heidelberg man (———), recent European (. . . . .) and African negro according to Schoetensack.

Fig. 3, upper right. Superimposition of mandibular profiles of Neanderthal child and recent one according to Keith.

Fig. 4, lower left. Superimposition of mandibular profiles of Heidelberg man and recent European according to the author.

Fig. 5, lower right. Superimposition of mandibular profiles of Neanderthal child and recent one according to the author.

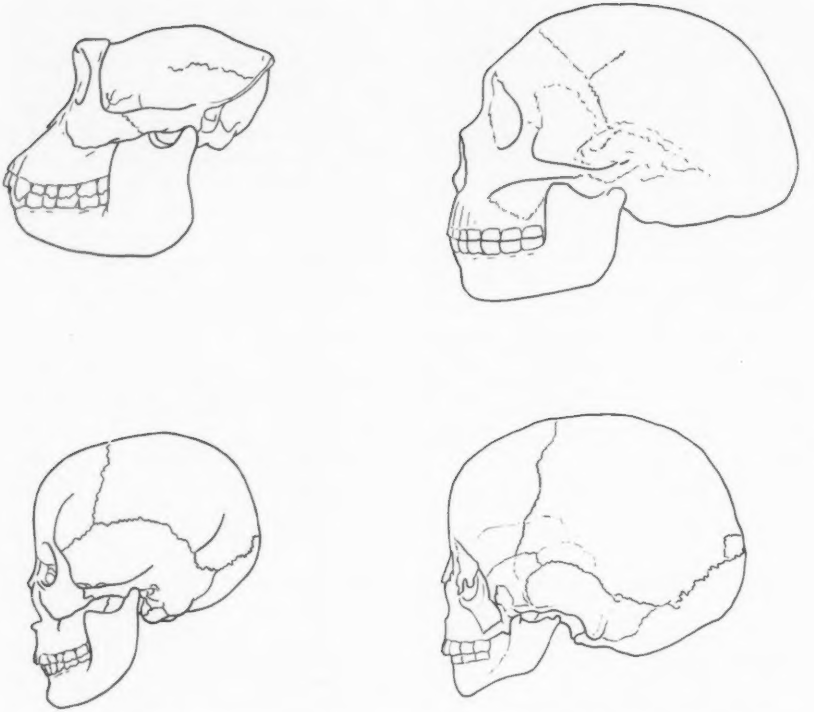


Fig. 6 Developmental stages: upper left, ape; upper right, early man; lower left, recent man; lower right, child.

gether. But why should it? Familiar with quanta and mutations, we are used to the idea that nature does not proceed in a continuous way but by leaps. So the emergence of the chin can be explained as a temporary lack of synchronization in these leaps. One of the next leaps may easily concern the chin which has so far escaped the general reduction trend.

Bolk and The Fetalisation Theory

The above given explanation would also be in conformity with Bolk's fetalisation theory. Bolk has demonstrated that the rise of Man is connected with the fact that conditions existing in earlier ontogenetic stages have become fixed. Apes and men resemble each other in their fetal stage much more than one would expect, judging from their adult state. Thus, while the masticatory apparatus develops into the snout in apes, this development in man comes to a standstill at a much less progressed stage. Another example: in the course of ontogenetic development the relatively high forehead of the child becomes flatter and more receding. This process, too, comes to its end in recent man earlier than in the Neanderthaler or in the ape. Figure 6 illustrates both these phenomena.

To these representatives of developmental types might very well be added

a constitutional type, to be inserted between the stages 3 and 4 of Figure 6. It is the *Cerebral Type* of the French school of constitutionalists. This type is characterized by a well-developed cerebral part of the skull with its especially high forehead. In contrast to this the facial part is less developed so the profile is nearly straight, with a small nose, narrow lips and a very flat chin which might be termed "underdeveloped". But this *underdeveloped* chin can be understood as *arrested* in its development at a more juvenile stage. It is well known that the chin starts its developmental career rather late, at and after puberty. The high forehead too can be explained in the same way, (Fig. 7). Comparing the developmental stages in the light of the fetalisation theory, we easily get the impression that the present day cerebral type is the latest form Nature has evolved on Man's way from past to future. And it is just here that the atavistic remnant called "chin" for the first time shows signs of a beginning reduction and thus falls into step with the general trend towards reductions of the whole masticatory apparatus.

Fig. 7 Maturation changes of the face. Above, after Gerhardt; below, after Martin.

Phylogenetics, The Teeth and Their Occlusion

After having found that reduction to an essential degree has taken place in the very region of the lower incisors —the chin excepted—it seems necessary to investigate how the reduction of these teeth themselves compares with it. This poses a certain difficulty, since early man is generally found as one specimen, rarely two, at a time. There were, however, two excavations where groups of Neanderthal people were found and which lend themselves to statistical treatment. The one place is Krapina (Yugoslavia), the other on Mount Carmel (Israel). In Table II we shall see that the mean value for upper and lower incisors in orthodontic patients is only about fifteen per cent smaller than in the extremely macrodont Krapina people and even ca. five per cent only in the Mount Carmel people. These reductions are of a rather moderate extent in comparison with the reductions which have taken place in the mandible. (Based on figures published by Hrdlicka, the author once computed the over-all length of a modern mandible to be thirty per cent smaller than that of the Heidelberg mandible and the thickness in the median line, measured midway from above, is reduced as much as even fifty per cent.)

Though this difference in reduction would explain the occurrence of crowding generally, it would not ex-

Table II

Incisor Widths in Palaeolithic people and orthodontic patients

	Krapina	Mount Carmel	Heidelberg	Ortho. patients
		Sum of the four upper incisor widths		
Minimum	34.8	29.4		25.0
Mean	37.6	33.8		31.8
Maximum	39.8	39.6		38.0
		Sum of the four lower incisor widths		
Minimum		21.0		17.5
Mean	27.4	24.0	23.6	23 1
Maximum		27.4		27.5

plain the higher percentage in the lower jaw and for this we shall have to consider the changes in position and occlusion which have taken place during the same period.

Psalidodonty (scissor bite) is today regarded as the "normal" bite; we must, however, not forget that this is a rather recent acquisition and that even at present labidodonty (edge to edge bite) is still the bite of Australian aborigines and Eskimos. It seems to the author that it is this change-over from labidodonty to psalidodonty which is responsible for the high frequency of mandibular incisor crowding. Looking at modern dental arches, we see well rounded incisal segments in the upper jaw; the lower incisal sector, however, is nearly straight, for the lower teeth have to arrange themselves *behind* the upper ones. If we compare these conditions with those of earlier times, we find the lower incisal segment equally well arched. Not confined *behind* the upper teeth but arranged *opposite* them, the incisors can fan out and adapt themselves to their antagonists. It should be mentioned that even in these early times labidodonty was not originally existent but was a product of ontogenetic development connected with the attrition of the teeth. But then, at a very early age, cusps and edges were worn down by attrition and abrasion due to primitive food habits and the admixture of sand and grit to the food. The lower incisors could leave their restricted position behind the crowns of the upper ones and occupy a segment, which was not only wider, but curved like the upper frontal arch. In Fig. 8 an attempt is made to arrive at an estimate of the reduction which has been caused by this change. The curved line A - B measures 26 mm., while the nearly straight line A' - B' is only 21 mm. long, i.e., ca. 20 per cent less. We have, however, just seen (Table II) that the teeth of recent men are on the average only between five to fifteen per cent smaller. We must not overlook the fact that, apart from averages, there crop up in recent man maximum values which almost reach those of

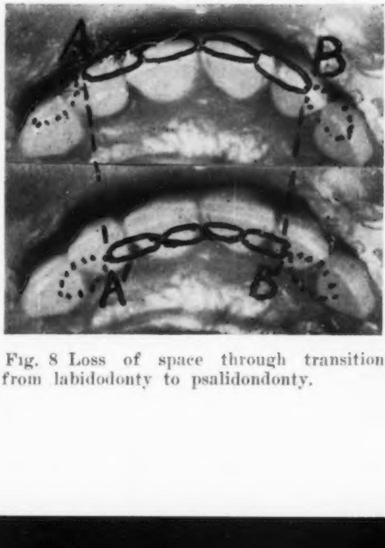


Fig. 8 Loss of space through transition from labidodonty to psalidondonty.

early man, while we shall never find a mandible today which could compare but slightly with that of Heidelberg man, for instance. It seems that here we find the underlying reason for today's mandibular incisor crowding.

Now, it might be argued that, when the lower incisors descend, phylogenetically speaking, from their edge to edge position and glide back to arrange themselves behind the upper incisors, they bring the whole lower arch into a more posterior position. But, as a matter of fact, skulls with labidodonty show the same occlusal pattern as exists in modern neutrocclusion interdigitation. Thus, the posterior segments remaining stable, the whole loss of space makes itself felt in the anterior sector which reacts by crowding.

Though we cannot follow DuBrul and Sicher when they speak of an *adaptive chin*, it would be possible to call the mandibular incisors *adaptive teeth*. Crowding is their response to the phylogenetic changes which have taken place. That this kind of adaptation is not an ideal one need hardly be said. Reduction in size or number would bring a real solution, of course, but this process has scarcely started. Table II has shown the modest amount of reduction in size which has taken place up to now, and congenital absence of lower incisors is so seldom and irregular as to be quite a negligible factor.

Dental Disharmonies

The phylogenetic approach shows us there exists an inherent tendency toward disharmony between the mandibular incisors and the space at their disposal. If this fact is regarded here as the primary reason for their so frequent crowding, there should, however, not be excluded the possibility that other causes might be involved too.

Various authors have mentioned the disrelation in the size of the upper and lower front teeth. Neff in 1949 proposed an anterior coefficient: in two hundred cases he found this coefficient ranging from 1.17 to 1.41. In his opinion the "ideal" ratio would be 1.20. Varying the degree of overbite according to the value of this coefficient, he believes in the possibility of a "tailored occlusion". In 1957 Neff has once more taken up the subject. He now introduces an anterior percentage relation (APR) and states that in three hundred malocclusions the maxillary anteriors are between 18 and 36 per cent larger than the lowers. He still recommends compensation for disharmonious segments by varying the overbite and even gives a table showing the "indicated overbite" for different values of APR. However, he also thinks that in some cases the extraction of a lower incisor might be necessary, and that in other cases stripping might be sufficient.

Lundström has treated the problem of anterior disharmonies on different occasions. In 1955 he tested an anterior index in 195 boys and 124 girls and found a range of 73 to 85, with a mean of about 79. He states that the degree of crowding is higher in individuals with big teeth, while those with small teeth tend toward spacing. In contrast to Neff he declares: "An adjustment of the overbite or overjet does not seem to be the method used by Nature for accommodation of disharmonies in the tooth width ratio between upper and lower jaws."

Bolton (1952), according to Neff, investigated fifty-five excellent occlusions and found a range of 74.5 to 80.4 with a mean of 77.2. He, too, could not find a relation between the ratio and the degree of overbite.

Ballard (1956) believes, in addition to disharmonies of upper and lower segments, left-right discrepancies, too,

Table III

Means, standard deviations, coefficients of variability and correlation coefficients of incisors and of molar circumferences

	Mean	St. Dev.	Coe. Var.	Coe. Cor.
Sum of upper incisor widths	31.81	2.24	7.07%	0.70
Sum of lower incisor widths	23.10	1.82	7.88%	
Upper molar circumferences	36.90	1.46	3.95%	0.78
Lower molar circumferences	36.16	1.72	4.75%	

should be taken into account. In five hundred cases he found that in 90 per cent one or more pairs of teeth showed such discrepancies. Ballard regards 75 per cent as the "normal or ideal total of the mesiodistal widths of the lower incisors." In four hundred orthodontic patients he found that this total was larger in 90.7 per cent; in 50.3 per cent it was larger by 2 mm or more, and in 31.5 per cent it was larger by 3 mm or more. On the basis of these findings he recommends stripping or, when the difference amounts to the width of a central incisor, the extraction of such a tooth.

All these publications were concerned with the front teeth, i.e., incisors plus cuspids. As this paper is devoted to the lower incisors, the author thought it opportune to make a special investigation limited to the relationship between upper and lower incisors. It was found that the mean for the Incisor Index was 73 per cent, with a range of 63 to 86 per cent, and therefore not much different from the means found for the anterior indices. It deviates from them by the much greater range which is nearly twice as large. The material for this investigation consisted of three hundred orthodontic patients.

There was also computed the correlation coefficient for the sum of the upper and lower incisor widths which was +0.70 ± 0.029. To give some interpretation of the meaning of this figure, the author has also calculated the correlation coefficient for the circumferences of the upper and lower first molars: +0.78 ± 0.023. As we know how different upper and lower molars can sometimes be in the same patient and as we see that their correlation, nevertheless, is higher than that between the incisors, we get some idea what disharmonies we may have to contend with, Table III and Fig. 9.

To this might be added that the incisors especially have a rather high genetic variability. This was demonstrated by Lundström in his investigation *Tooth Size and Occlusion in Twins* (1948). Ballard's (1956) obser-

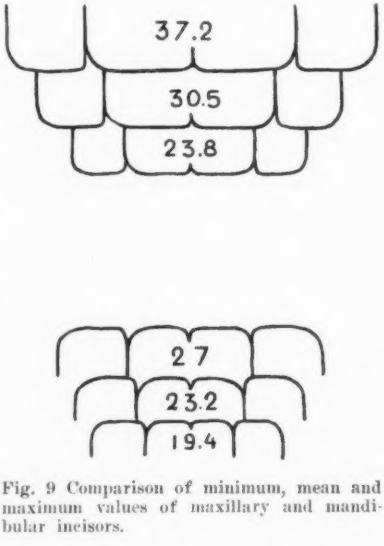


Fig. 9 Comparison of minimum, mean and maximum values of maxillary and mandibular incisors.

vations have been reported above, and only recently Horowitz, Osborn and DeGeorge (1958) in their publication *Hereditary Factors in Tooth Dimensions* came to the following conclusion: "When mesiodistal tooth dimensions are used to establish orthodontic diagnosis ratios, the findings of this study suggest that the anterior teeth be considered as two separate groups, the 'variable' incisors and the relatively 'stable' canines".

Teeth — Jaw Disharmonies

Among the possible disharmonies remains that between the size of the incisors and the size and form of the mandible to be investigated. As the author has repeatedly treated the subject of disrelations on a constitutional basis, it might suffice here to mention that crowding can result from the appearance of large teeth in relatively small or narrow mandibles. The importance of such disrelations was first stressed by Axel Lundström and this problem has since been dealt with under the term of "apical base". There was, however, always a certain vagueness about it, and the author has tried to put the teeth-jaw relationship on a more concrete basis by his Zygomatic Method. This method has been sufficiently described in earlier publications, so that there seems to be no need to go into it once more. This might, however, be a good opportunity to mention some recent investigations concerning the validity of this method.

Markowitsch of Basle University (1957) has confirmed the zygion-molar relationship in an investigation of twelve hundred children and adults. He thinks, however, to get still better results by replacing the bizygomatic measurement with the bitragial breadth.

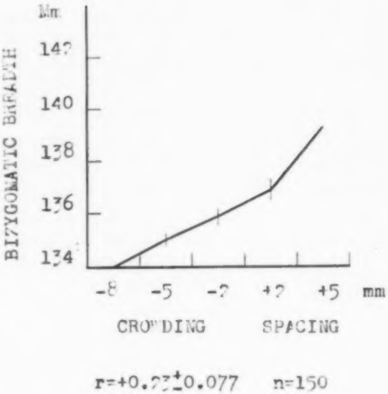
Another and especially interesting test of the author's Zygomatic Method has been made by Moorrees in his investigation of the *Aleut Dentition* (1957). In this Eskimoid people, he found the index: bizygomatic breadth over bimolar width to be 33.2 as against the required 33.3. Commenting on this result and comparing it with investigations by Meredith and Higley, Moorrees writes: "These authors from their own data and those of others reported a wide range of variation (0.18 to 0.88) for this correlation coefficient. It should be noted, however, that the different samples reviewed varied in age, in methods of measurements and in the manner in which growth increments for bizygomatic breadth in children were taken into account, a fact which explains the highly variable findings reported by different investigators. For thirty-four Aleuts the coefficient of correlation between arch breadth and bizygomatic breadth is $+0.74 \pm 0.076$ which indicates a rather high degree of association between these two measurements".

It seems that these rather critical remarks by Moorrees also hold good for the latest publication by Hixon and Meredith (1957). Regarding this paper the author cannot but point out one rather astonishing inaccuracy. In describing the Disrelation Table which is an off-shoot of the Zygomatic Method, Hixon and Meredith write: "The chart is diagnostic in that it is partitioned into zones designated 'lack of space', 'harmony' and 'excess of space'. The major interpretation made is that for those patients falling in the 'lack of space zone', the only solution for successful treatment is extraction . . .". Now, as a matter of fact, the original chart has not three zones as reported above but five, i.e., besides the zones mentioned above there is a zone of "extreme excess of space" and one of "extreme lack of space". And the author's remark about extraction as the only solution as quoted by Hixon

and Meredith did refer to this latter zone of extreme lack of space. It might well be stated here that the author never thought of the Disrelation Table as the one and only criterion of extraction therapy. It was proposed as an addition to existing diagnostic procedures in order to facilitate a sometimes difficult decision.

Returning to our problem, it will not seem astonishing after the preceding discussion that the author tried to demonstrate the occurrence of teeth-jaw disharmonies with the help of the bizygomatic measurement, though the outlook was not promising. For even in the upper jaw the relation between the bizygomatic breadth and the anterior parts of the dental arch had proved to be rather weak in contrast to that existing in the molar region. The correlation coefficient of $+0.23 \pm 0.77$ for the relation between crowding and the bizygomatic breadth did not come as a surprise; it is low and just at the level of significance. As a kind of surprise, however, there appeared a coefficient of practically nil for the correlation between crowding and the bigonial breadth, which was computed at the same time and with the same material (one hundred fifty orthodontic patients). On the other hand, a correlation coefficient between crowding and the sum of the lower incisor diameters proved to be as high as -0.56 ± 0.56, which means that the bigger the teeth, the greater the lack of space as expressed by amount of crowding, Figs. 10 and 11.

Though we cannot directly prove teeth-jaw disharmonies, the very fact that crowding is so strongly correlated with incisor size makes them very probable. As a matter of fact, the disharmonies produced by the greater reduction of the mandible and the lesser one of the teeth during phylogeny—described above— would already fall into this category of teeth-jaw disharmo-



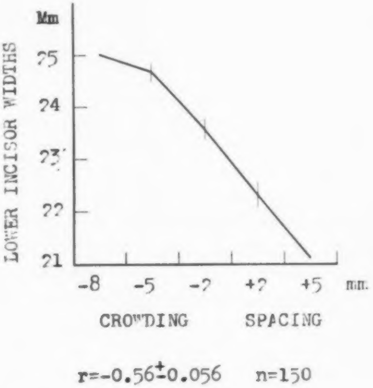


Fig. 10, above. Correlation of bizygomatic breadth with crowding and spacing of the lower incisors.
Fig. 11, below. Correlation of the sum of the lower incisor widths with crowding and spacing.

nies. To these would now have to be added those where big teeth appear in constitutionally small and/or narrow mandibles as connected with leptosomic or cerebral types.

Dynamics

Having up to now and at some length treated what might be termed static conditions concerning the lower incisors, we shall now have to con-

sider some aspects which might constitute their dynamics.

First among them is growth and development. The spacing of the deciduous incisors is a good indicator of the growth taking place in this region between the ages of three to six. If there is not enough room at that time, the lateral incisors erupt lingually. But they may still find their normal places —under the influence of function and muscle pressure—if more space will accrue by local growth at this "late" age. To understand the meaning of "late" in this context, it should be remembered that, as far as addition of space is concerned, growth in this particular region stops at that time. In an investigation of twenty-eight individuals from 3 to 15 years of age, Woods found that the canine width, measured between the tips of their cusps, increased on the average by 0.9 mm. in boys, by 0.6 mm. in girls, i.e., remained practically stable. Therefore, hopes for the relief of crowding by later growth are doomed to disappointment. Space gained by the replacement of the deciduous molars through their smaller successors is generally taken by the mesial drift of the six-year molars.

There have been interesting investigations with respect to changes in place and inclination of the lower incisors. Schaeffer as well as Björk and Palling found that such changes do not occur in one direction only. Some incisors increased their labial inclination, others their lingual one, and some did not alter their inclination at all.

Occasionally one reads that besides changes of inclination, the over-all position of the incisors is changed into a more lingual one. Such statements are accompanied by pictures where the backward movement is measured from pogonion as the point of departure. But pogonion is in an especially vehement developmental stage during and after puberty. Gerhardt in his monograph about *Maturation Changes of the Human Physiognomy* has found that not only the inclination of the chin alters, but also changes of its configuration. He distinguishes three basic shapes. Meredith reports changes of up to 2.6 mm in the depth of the anterior concavity, reflecting upon the development of the pogonion, even during the prepubertal period (4 to 14 years). It would, therefore, seem that we have to observe extreme reserve when meeting with conclusions regarding the incisor position in relation to pogonion. (See also Fig. 7.)

The influence of the muscles must be mentioned among the dynamics of the lower incisors, too. One is inclined to think that an equilibrium between the pressure of the tongue from within and the buccal and labial musculature from without is conducive to a stable position of the teeth generally and the incisors in particular. These, however, are general considerations and the recent investigation of a special instance of muscle behavior might be of interest in connection with this problem. Sims measured perioral and lingual muscle pressure exerted upon the maxillary and mandibular central incisors and came to the conclusion that there exists no relation between the inclination of the incisors and the amount of pressure. We should, therefore, for the time being still use a certain caution when speaking about the influence of the muscles on the lower incisors.

Another question to be considered in this context is that of *bite raising*. This was regarded rather optimistically until a few years ago. But Thompson's investigations brought about a more realistic approach and the limiting influence of the muscles is now recognized. It should be with extreme caution that we try to get

more space for the arrangement of the lower incisors by bite raising, as, for instance, envisaged by Neff in his *tailored occlusion* or *indicated overbite* proposals.

Related to the influence of muscles is that of habits, part of which is but a perverted muscle action. It seems rather superfluous to state that the lower together with the upper incisors are the teeth most of all exposed to displacement by habits. Differences in the resulting anomalies are due to the varying combinations of duration, frequency and intensity, as has recently been emphasized by Graber. It might, however, be added that these habits will superimpose their influence on the existing pattern only and will not change an originally existing tendency towards crowding or spacing.

Diagnosis

On the basis of the above theoretical considerations we shall now see what conclusions we can draw for the practical application in diagnosis and treatment.

Newer diagnostic procedures following the lead of Tweed are centered around the lower incisors. At the start came the postulate of an angle of 90° between the axis of the lower incisor and the mandibular plane. This was later complemented by the introduction of the Frankfort mandibular plane angle; and finally the Frankfort-lower incisor angle was arrived at. Thus, all the angles of the Frankfort-mandibular plane triangle have successively come into play and, if one is inclined to say so, one could state that this triangle has now run full circle. As the angles of a triangle add up to 180° and two angles were already fixed at 90° and at ca. 25°, this new relationship does not mean anything essentially new, but simply follows as a mathematical consequence.

The question now arises whether the angulation of these teeth is really as important as these continual diagnostic endeavors would have it appear. To a certain degree this question has already been answered. Wylie (1955), testing cases treated by Johnson and by Tweed himself, found no correlation between the uprighting of the lower incisors and changes in the angle of convexity. The greatest change (16°) actually occurred in a patient where the lower incisors were tipped even 1° forward while the greatest amount of tipping (24°) produced a change of 9° only in the convexity angle. Wylie therefore, comes to the conclusion that "all these years orthodontists have been attaching exaggerated importance to the angulation of the lower incisors, so far as it is concerned in orthodontic diagnosis and treatment planning." Essentially the 90° angle was a prosthetic principle taken over into orthodontics, and its usefulness there has been doubted. Wylie's investigation proved that these doubts were absolutely justified.

Another point should also be considered: in the introduction it was remarked that apparently the six year molar had lost its position as key to occlusion and has been replaced, at least to a certain extent, by the lower incisors. Massler and Frankel, in an investigation of 2758 children, came to the conclusion that the lower incisors were the most frequently displaced teeth, the upper first molars the least ones. There does not seem to be much advantage in replacing the relatively stable teeth by such unstable ones in diagnostic procedures. How unstable these teeth really are, the author hopes to have shown in the earlier part of this paper. There the teeth have been characterized as "adaptive", because they adapt themselves to the reduced space at their

disposal and according to their size. Their position is basically a resultant of these two factors, and the correlation coefficient of -0.56 shows that size is the more important one.

Now, following up the idea of adaption, we should have to ask: to what special condition have the incisors to adapt themselves? The answer would be: to the position of their neighbors, the cuspids. Earlier in this paper it was reported that the bicanine width remains practically stable. So it seems that it is this width which determines the fate of the incisors. If the incisors are small, they will arrange themselves well within this space; but they will have to crowd into it, if they are big. When they are very small and there is much room at their disposal, there will be spacing.

We are led to believe that rather than to center our interest upon the incisors and their angulation, we should consider the cuspid position as the point of departure. There is, however, no action without reaction, and we have learned from our anchorage problems that a tooth cannot be moved without to some degree influencing the anchor tooth or teeth. Consequently, the retention of the incisors produces some reaction in the cuspids. This reaction in the cuspids expresses itself by tipping. And, if just now the position of the cuspids was proposed as a point of departure, we will have immediately to correct ourselves and to add that in the last instance it is the cuspid apex position which is decisive. The same action - reaction mechanism is, of course, at work in the cuspid - bicuspid relation, too, and thus the tipping of the cuspids may also come to some degree under the secondary influence of the bicuspids. Though this need not concern us here, a careful analysis will have to be made when planning treatment.

Treatment

If one accepts the foregoing argumentations, one of the first practical conclusions would be: not to base diagnosis and treatment planning upon the four lower incisors and their angulation mainly. Taking into account the reduction of the anterior part of the mandible and the possible disharmonious size of the teeth, our main concern would be to find a solution which would disturb the position of the lower cuspids, i.e., their apices, as little as possible. This means that we would first of all have to imagine them in a upright position and to calculate how much space would then remain available for the arrangement of the incisors. If there would be lack of space of more than about 3 mm, the best solution would be to extract an incisor. Such a procedure has occasionally been advocated by Neff, Ballard and others. It is, however, apparently not accepted as a routine measure for Salzmann recommends: "Incisor teeth should not be extracted unless damaged beyond satisfactory repair".

The author thinks that the recent tendency to use these teeth as a kind of "keys" to diagnosis and treatment planning has elevated them to such a state of importance as to make the weakening of the "key ring" as something not to be thought of. The approach to the problem, however, as pursued here, would make the reduction of tooth material between the cuspids the logical solution. And to translate this into practice is rather easy, if, as has just been stated, there is a lack of space of 3 or more mm. The author prefers the extraction of a lateral incisor as he finds that the distal side of a central incisor fits rather well the mesial part of the cuspid, whereas the extraction of a central brings the mesial side of a central

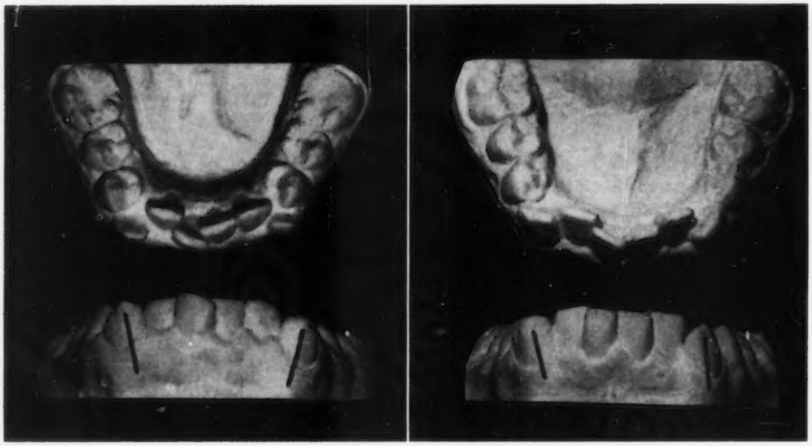


Fig. 12, left; Fig. 13, right.

and the mesial of a lateral together and, even when the teeth are perfectly uprighted and parallel, there sometimes persists an awkward empty triangle between the lower half of the teeth and the gingiva.

Extraction of this kind is easily decided upon when there exists a certain asymmetry, one lateral in a lingual position and the adjacent cuspid tipped outward or backward. If there is more lack of space than that of an incisor width, the extraction of two premolars is the best solution. There may, however, be cases where both cuspids are tipped backward to a considerable degree. To bring them back into the premolar space would not only entail uprighting but also a consecutive extensive bodily movement. In these rare cases extraction of both laterals seems, if not ideal, still the relatively best solution. (Fig. 12).

The direction of tipping may also become decisive when the incisor position is symmetrical, both laterals being lingually displaced, of which, however, only one need be extracted. If in such a case one cuspid should be tipped forward and one backward, the lateral beside the latter should be extracted for uprighting this cuspid is already half the treatment, while on the other side bringing the forward-tipped cuspid into the extraction space of the lateral would require moving it farther in the direction of tipping and would necessitate extensive bodily movement (Fig. 13).

If the lack of space is less than 3 mm, the decision might become rather difficult. One just can resign oneself to the situation and take a certain amount of crowding into account, as advocated by Howes; or one could resort to stripping. Up to now the author has never practiced it, but he remembers certain cases where the peculiar form of the incisors, wide at the edges and strongly tapering towards the gingiva, posed a real problem and stripping might have been the solution. Progress in impregnation techniques, like fluoridation, might overcome one's still existing reluctance. Finally, in these cases of not-so-pronounced lack of space, there still remains the conservative treatment by widening, es-

pecially if this would be in conformity with the need of some expansion in the upper jaw.

Needless to say that these are elementary points only, to be considered in lower incisor treatment. There certainly is room for further improvement in differential treatment planning. Besides there is a possibility for a wide range of combinations as extraction of a lateral on one side and of a bicuspid on the other, or extraction plus widening, when just a little more space than one incisor width is lacking, etc.

Summary

Considering the lower incisor problem from different points of view, we are led to the conclusion that the crowding of these teeth is mainly a result of an evolutionary process. It can also be caused or may be aggravated by disrelations either with the upper incisors or with the bony base. Consequently, crowding has to be understood as an adaptive response to changed conditions, as the incisor's contribution to an equilibrium of static and dynamic forces which it would seem unwise to disturb. Therefore, for practical purposes, the position of the lower cuspids, or still more exact, the position of the lower cuspid apices should be regarded as stable and the treatment of the incisors should be planned in such a way as to arrange them within the given limits, if need be, by reduction of tooth material. It goes without saying that though the treatment of the lower incisors should be planned in each case individually and on its own merits, it should fit into the over-all treatment, but it should be regarded there as of secondary importance only.

Of recent years it has become accepted to speak of the science and art of orthodontics. So we might do worse than to go to the world of art in order to find a simile for lower incisor treatment. The author likes to compare the lower incisor treatment to the cadenza in a concerto. The cadenza has its place at the end of the first movement, after the principal themes have been played and developed; it is here that the artist has the possibility to improvise, keeping himself only loosely to the theme or themes. In the same way treatment of the lower incisors should be initiated when the case has progressed for some time along the principal lines, and the play of the appliances and the counterplay of the patient and his tissues has sufficiently developed to reveal the character and peculiarities of this special case. Then the treatment of the lower incisors may become a rather short, though important, episode within the entire treatment as also is the cadenza within a concerto. And, as the cadenza will tax the performer's artistic skill and musical understanding, so the handling of the lower incisors calls for the happy combination of the orthodontist's clinical experience and his scientific knowledge.

69 Rothschild Blvd.

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A Metric Analysis Of The Facial Profile*

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This investigation pertains to the integumental profile of the face in childhood. It describes a quantitative method for depicting the facial profile and presents a number of findings from application of the method.

The integumental profile is measured with respect to a line passing through nasion and pogonion. Distances perpendicular to this line are measured, these distances terminating anteriorly at selected points on the facial profile. Supplementary data are obtained to determine (a) positional relations among the measures perpendicular to the nasion-pogonion-line, and (b) the angular relation of the nasion-pogonion line to a cranial-base line.

The measures are obtained from *norma lateralis* radiographs of the head taken on North American white children. Each of 26 girls and 22 boys are studied at two postnatal ages nine years apart.

STATEMENT of OBJECTIVES

Specific aims of the study were:

1. To devise a metric method for describing the integumental profile of the face and to investigate reliabilities for various facets of the method.

2. To investigate age, sex, and individual differences in the integumental profile of the face. Basic in the realization of this objective were computations of univariant statistics for (a) measurements of the integumental profile at ages 5 and 14 years, and (b) changes in the integumental profile between ages 5 and 14 years.

3. To study associations between components of the integumental profile. This entailed determining bivariant statistics for different aspects of the profile at ages 5 and 14 years, giving particular attention to (a) size at age 5 years in relation to change between 5 and 14 years, and (b) association between age changes in different profile components.

PERTINENT LITERATURE

The literature pertaining to facial size and form was examined in an effort to locate previous research on the integumental profile of the face. Search was made for methodologic proposals and reported findings on children and adolescents.

Five relevant publications were found, two[2, 3] presenting methods of describing the facial profile, one[10] dealing with age and sex differences for height and depth measures of the profile, and two[1, 6] reporting findings on change with age in the angle between a facial-height line and a cranial-base line.

Elsasser[3] constructed a facial orthometer that provided a reference axis anterior to the profile and at right angles to the Frankfort plane. Direct measurements were proposed (a) from the axis posteriorly to three points on the integumental profile, i.e., points estimated to lie in the same horizontal planes as nasion, subnasale and pogonion, also (b) along the axis from the estimated level of nasion to sub-

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nasale and to the lowest point on the integumental chin.

A method of studying the facial profile on *norma lateralis* radiographs was developed by Burstone.[2] This proposal calls for the determination of series of angles (a) between pairs of lines drawn to selected points along the integumental profile and (b) between lines along the profile paired with a line passing through the anterior and posterior nasal spines.

Pelton and Elsasser,[10] utilizing the Elsasser orthometer, derived two measures each of the forward and downward growth of the integumental profile. They amassed and analysed data for these measures on 3,676 white males and 3,153 white females between 5 and 25 years of age.

Bjork[1] and Lande[6], each studying males only, determined the angle between a facial-height line and a cranial-base line at different ages separated by approximately nine years. The means of Bjork are based on cross-sectional data, those of Lande largely on longitudinal data. Lande studied 20 boys at age 3 years and 32 boys at age 12 years; Bjork's samples numbered 322 at age 12 years and 281 in young adulthood.

The Elsasser and Burstone publications are cited for their methodologic relevance. Findings from the investigations of Pelton and Elsasser, Lande, and Bjork are pertinent for later comparison with findings from the present study.

Subjects

The subjects were 48 American-born white children, 26 girls and 22 boys. All were normal, healthy children participating in a longitudinal research program at the State University of Iowa.* The children were enrolled for study on the basis of willingness to cooperate and the likelihood of continued residence in the vicinity. They were not selected on the basis of facial characteristics or orthodontic needs.

Ninety-six per cent of the subjects had at least two grandparents of northwest European descent. For 76 per cent of the subjects, all four grandparents were of northwest European ancestry.

Seventy per cent of the fathers held professional or major managerial positions. Over 20 per cent were in the minor managerial, commercial or skilled trade groups, and the remainder were employed at semiskilled occupations.

Source of Data

The source of all data was *norma lateralis* radiographs of the head, drawn from the files of the Facial Growth Study.* In this Study radiographs of every subject are taken on or near each birth anniversary, and at semiannual intervals up to 12 years of age.

Those subjects included in the present investigation were required to satisfy the following criteria:

1. Radiographs on file at ages 5 and 14 years, each showing good soft tissue definition.
2. Molar teeth in occlusion.
3. Lips in contact, or nearly so. The latter was accepted when, from examination of serial radiographs, slight lip separation was considered the normal position for the child.

Landmarks and Measurements

Osseous landmarks used in determining the reference and cranial-base lines were:

1. Nasion, defined as the most anterior point of the frontonasal suture.[5]

*This program, known as the Facial Growth Study, is under the joint direction of E. H. Hixon, Department of Orthodontics, and H. V. Meredith, Child Welfare Research Station.

2. Pogonion, defined as the most anterior point of the mandible found by means of a rule moved at right angles to the mandibular plane.[5]

3. Tuberculum, defined as the most superior point of the anterior outline of sella turcica before the outline turns and continues forward.[12]

A line from nasion to pogonion was drawn on each radiograph. Using a rule moved at right angles to this reference line, five pairs of points were marked with a needle probe. The posterior point of each pair was on the nasion-pogonion line and the anterior point of each pair on the integumental profile. The levels for placement of these points were found by locating:

1. The minimum distance from the nasion-pogonion line to the integumental concavity at the root of the nose.

2. The distance from the nasion-pogonion line to the tip of the nose.

3. The minimum distance from the nasion-pogonion line to the concavity of the upper lip.

4. The minimum distance from the nasion-pogonion line to the labiomental groove.[11]

5. The distance from the nasion-pogonion line to the most forward point of the convexity of the integumental chin.

These landmarks were used in obtaining two series of linear measurements. The first series represented anteroposterior distances between each pair of points (see Figure 1). The second series represented distances along the nasion-pogonion line; from nasion to the first level, between the first and second levels, and so forth.

The measurements were obtained directly on the marked radiographs by use of a steel tape calibrated in millimeters. All readings were taken with the aid of a magnifying glass and estimated to the nearest 0.1 mm. The calibration of the tape was checked for accuracy against a standard scale.

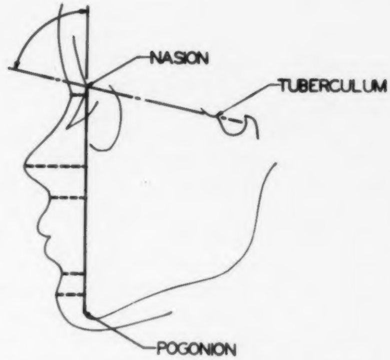

Fig. 1 Illustration of the method used for metrically describing the facial profile.

A cranial-base line, drawn through nasion and tuberculum sella, formed an acute angle with the nasion-pogonion line. This angle was measured on each radiograph by means of a calibrated drafting machine with a vernier scale. All angles were measured to the nearest minute.

Reliability of Data

Two problems pertaining to the reliability of the data were investigated. Both were studied on the 26 female subjects and dealt with distances from the nasion-pogonion line to the facial profile.

The first problem considered the agreement of two measurers, working independently, in determining the distances between the pricked anterior landmarks on the integumental profile and the pricked posterior landmarks on the nasion-pogonion line. Each distance was measured to the nearest 0.1 mm, and all five distances were determined at ages 5 years and 14 years. The extent to which a record obtained by measurer A differed from the corresponding record obtained by measurer B was determined.

Over the entire series, this gave 260 difference values. The standard deviation for these values was 0.10 mm, and the standard error of measurement 0.07 mm.[1]

The foregoing analysis treats one phase of the dependability of the data, i.e., chance variation in measuring between the points registered on the radiographs. Additional chance variation is associated with positioning the subject, radiographic processing, drawing the nasion-pogonion line, and registering the measurement landmarks. For the study of these sources of unreliability, the desirable materials would be several independently obtained radiographs for each subject representing the same age. Since only single radiographs were available for a given age, it was necessary to employ a substitute procedure.

For each subject, single radiographs were on file at semiannual ages from 4.5 years to 11.5 years, and at annual ages from 12 years on. It was decided to investigate reliability using pairs of radiographs taken at a specified age and six months later. Two growth stages were selected, 5.0-5.5 years and 11.0-11.5 years. The 26 female subjects were studied at both stages.

Each radiograph was dealt with by following the same series of steps as were projected for deriving the basic data to be used in the study. These steps have been described to the point of independent measurement of the five dimensions from the nasion-pogonion line to the facial profile. When the two records for a dimension differed by no more than 0.2 mm, their mean was employed. When the difference between the two records was 0.3 mm or more, two additional measurements were taken, the most divergent of the four was discarded, and the mean of those remaining was employed. The composite values for each dimension were corrected for radiographic enlargement.[9]

Analysis by age-level and specific dimension gave the reliability estimates presented in Table I. Each correlation coefficient depicts the association between corresponding measurements of a facial dimension derived from two radiographs taken six months apart. It will be seen that eight of the ten r's are 0.9 or higher.

Findings

The findings of the study will be presented under four captions: profile distances measured perpendicular to the nasion-pogonion line, profile distances measured along the nasion-pogonion line, angular relationship of

Table I

Reliability estimates for five dimensions proposed in metrically describing the integumental profile of the face

Dimension	r 5.0-5.5 years	r 11.0-11.5 years
Nasion-pogonion line to:		
Root of nose	.92*	.91*
Tip of nose	.93	.98
Concavity of upper lip	.90	.96
Labiomental groove	.85	.93
Convexity of chin	.72	.96

* In each instance, N=26 female subjects.

Table II

Central tendency and variability values (mm) for five distances from the nasion-pogonion line to the facial profile

Level of Dimension	Sex	N	Age 5 years Mean	Age 5 years S.D.	Age 14 years Mean	Age 14 years S.D.
Root of nose	Girls	26*	6.3	0.8	6.6	0.8
	Boys	22*	6.6	0.7	7.1	0.8
Tip of nose	Girls	26	23.8	1.6	30.9	2.9
	Boys	20**	24.5	2.1	32.0	3.5
Concavity of upper lip	Girls	26	14.5	2.1	16.3	2.6
	Boys	22	14.7	1.6	17.5	2.3
Labiomental groove	Girls	26	9.7	1.5	9.9	1.7
	Boys	22	9.5	1.8	9.5	1.9
Convexity of chin	Girls	26	11.3	1.3	12.3	1.4
	Boys	22	11.4	1.5	12.4	1.6

* For samples of this size, the range of a distribution approximates the S.D. (standard deviation) multiplied by 3.8.

** Two radiographs did not include the tip of the nose at age 14 years.

the nasion-pogonion line to a cranial-base line, and selected illustrations of individual differences in facial profile.

The basic values for distances along the nasion-pogonion line were derived by the same measurement and adjustment procedures as those for the distances perpendicular to the nasion-pogonion line.

On no radiograph did two independent measures of the pogonion-nasion-tuberculum angle differ by more than 0.3 degree. Values for analysis were obtained by averaging each pair of these measures. Angles require no correction for radiographic enlargement.[13]

Profile distance measured perpendicular to the nasion-pogonion line. Table II displays central tendency and variability values for five distances from the nasion-pogonion line to the facial profile. Separate analyses are shown for children of each sex at ages 5 years and 14 years. The statistics of this table support the following findings:

1. Mean distances perpendicular to the nasion-pogonion line are (a) shorter to the root of the nose than to the labiomental groove, and (b) shorter to the most anterior point of the convexity of the integumental chin than to the most posterior point of the concavity of the upper lip.

2. At 5 years of age, both sexes combined, the obtained means for perpendicular distances from the nasion-pogonion line to the integumental profile are 6.4 mm at the root of the nose, 9.6 mm at the labiomental groove, 11.3 mm at the convexity of the chin, 14.6 mm at the concavity of the upper lip, and 24.1 mm at the tip of the nose.

3. All of the differences between corresponding means for the two sexes are under 1.0 mm at 5 years of age, and under 1.5 mm at 14 years of age. In no instance does a sex difference in standard deviation exceed 0.6 mm. At age 5 years, for none of the five dimensions is there a statistically significant difference between the distributions on girls and boys. At age 14 years, the only statistically significant difference is that between the means

for distance from the nasion-pogonion line to the root of the nose ($t = 2.0$).[4]

In several instances, the statistics presented in Table II suggest an increase in central tendency and/or variability with age. By pooling the data for the two sexes, larger N's were obtained for testing the dependability of age changes. Changes in central tendency significant at the 1 per cent level of confidence[7] are found for the distances from the nasion-pogonion line to the root of the nose, the tip of the nose, the concavity of the upper lip, and the convexity of the chin. The only dimensions for which the magnitude of the increase between ages 5 and 14 years exceeds 1.0 mm are those from the nasion-pogonion line to the deepest concavity of the upper lip (2.3 mm) and from the nasion-pogonion line to the tip of the nose (7.3 mm). The latter dimension stands alone in yielding a statistically significant difference in variability with age.[4]

Since the same sample was studied at ages 5 and 14 years, the data of this section could be utilized to investigate the following relationships: (a) association between the magnitude of a given dimension at 5 years and the change in this dimension over the period 5 to 14 years, and (b) association between the change in a given dimension over the period 5 to 14 years and the change in another dimension during the same period of childhood. Correlation coefficients symbolizing both types of relationship are assembled in Table III. Inspection of this table shows:

1. For none of the five dimensions is there a strong association between size at age 5 years and change in size during the ensuing nine-year period. The obtained r's all lie between zero and ± 0.4 Size-change concomitance is low positive for the distance from the tip of the nose to the nasion-pogonion line, and low negative for the distances from the root of the nose to the nasion-pogonion line and from the most forward point on the convexity of the integumental chin to the nasion-pogonion line.

2. Over the age interval 5-14 years, the amount of change at one level of the facial profile is not highly related to that at other levels. Moderate positive associations (r's between 0.4 and 0.7) are found for (a) change at the level of the tip of the nose with that at the level of deepest concavity of the upper lip, (b) change at the level of the labiomental groove with that at the level of the anteriormost projection of the integumental chin, and (c) change at the level of deepest concavity of the upper lip with that at the level of the labiomental groove.

Profile distances measured along the nasion-pogonion line. Measures along the nasion-pogonion line were obtained for the distance from nasion to the level of the integumental root of the nose; the distances between profile levels 1 and 2, 2 and 3, 3 and 4, 4 and 5; and the distance from nasion to pogonion. These measures were subgrouped according to age, sex and dimension, then analyzed for central tendency and variability. The results are arranged in Table IV. Representative findings are:

1. The mean distance along the nasion-pogonion line from nasion to a perpendicular passing through the root of the integumental nose is greater in early childhood than during adolescence. For both sexes combined, the obtained means are 3.2 mm at age 5 years and 2.0 mm at age 14 years. An appropiate significance test,[7] by supporting rejection of the null hypothesis at the 1 per cent confidence level, allows the inference of a decrease in this dimension with age.

Table III

Relationships among magnitude and increment data for five measures from the nasion-pogonion line to the integumental profile of the face

Measure	N	r	P*
Size at age 5 years with change 5-14 years			
Root of nose	48**	—0.30	<0.05
Tip of nose	46	0.36	<0.05
Concavity of upper lip	48	0.02	...
Labiomental groove	48	—0.18	...
Convexity of chin	48	—0.31	<0.05
Change 5-14 years at different levels			
Root of nose: Tip of nose	46	0.21	...
Tip of nose: Concavity of upper lip	46	0.67	<0.01
Tip of nose: Labiomental groove	46	0.16	...
Concavity of upper lip: Labiomental groove	48	0.43	<0.01
Labiomental groove: Convexity of chin	48	0.67	<0.01
Tip of nose: Convexity of chin	46	0.25	...

* Probability that the population r is zero.

** Children of both sexes.

Table IV

Central tendency and variability values (mm) for six distances along the nasion-pogonion line

Measurement	Sex	N	Age 5 years Mean	Age 5 years S.D.	Age 14 years Mean	Age 14 years S.D.
Nasion to level 1*	Girls	26	2.8	2.3	1.9	1.6
	Boys	22	3.7	1.8	2.1	2.4
Level 1 to level 2	Girls	26	27.2	2.6	36.9	2.8
	Boys	20**	27.6	3.1	39.1	4.5
Level 2 to level 3	Girls	26	12.5	1.7	17.3	2.0
	Boys	20**	12.6	1.9	18.0	2.1
Level 3 to level 4	Girls	26	29.8	3.4	31.4	3.9
	Boys	22	31.0	3.0	32.9	3.0
Level 4 to level 5	Girls	26	7.4	1.8	10.2	2.5
	Boys	22	8.6	1.9	11.6	2.3
Nasion to pogonion	Girls	26	86.7	4.5	105.5	5.7
	Boys	22	90.4	4.4	111.0	6.5

* The successive levels represent (1) root of the integumental nose, (2) tip of the nose, (3) most posterior point on the concavity of the upper lip, (4) labiomental groove, and (5) most anterior point of the integumental chin.

** Two radiographs did not include the tip of the nose at age 14 years.

2. At age 5 years, mean distances between the successive lines drawn perpendicular to the nasion-pogonion line are, for the two sexes pooled, 27.4 mm, 12.5 mm, 30.4 mm and 8.0 mm. The comparable means at age 14 years are higher by 10.6 mm, 5.1 mm, 1.7 mm and 2.9 mm, respectively. For each of these vertical distances a statistically dependable change with age may be posited, *i.e.*, the hypothesis of no change is untenable at the 1 per cent confidence level.

3. The mean vertical distance between the root and tip of the integumental nose is about 3.0 mm shorter at age 5 years than the mean vertical distance between the deepest concavity of the upper lip and the labiomental groove. At age 14 years the former distance (levels 1 to 2) exceeds the latter (levels 3 to 4) by more than 5.0 mm. It follows that for the age period 5 to 14 years there is much greater vertical increase in the nasal region of the integumental profile than in the labial region.

4. The mean distance from nasion to pogonion is greater for boys than girls. A sex difference significant at the 1 per cent level of confidence is found at each age. With two exceptions, the other differences between corresponding means on boys and girls are not dependable statistically; significance at the 5 per cent level is found for distance from the labiomental groove to the most forward point on the integumental chin at age 5 years, and for distance from the root to the tip of the integumental nose at age 14 years.

5. Combining data on both sexes, the mean distance along the nasion-pogonion line from a perpendicular passing through the root of the nose to a perpendicular passing through the anteriormost point of convexity of the integumental chin is 78.1 mm at age 5 years and 98.4 mm at age 14 years. The portion of this vertical dimension lying above the perpendicular passing through the point of deepest concavity of the upper lip increases from 51 per cent at the earlier age to 56 per cent at the later age. This relative increase harmonizes with findings by Meredith, Knott and Hixon[8] on changes during childhood in the nasal and subnasal components of skeletal face height.

Angular relationship of the nasion-pogonion line to a cranial base line. Table V presents central tendency and variability statistics derived from measures of the acute angle formed on drawing straight lines on each radiograph from pogonion to nasion and from nasion to tuberculum sella. It is found:

1. The means obtained at age 14 years are larger than those obtained at age 5 years by 3.7 degrees and 3.5 degrees on girls and boys, respectively. For both sexes combined, it is possible to reject at the 1 per cent level the hypothesis that the angle does not differ at the two ages.

2. At each age, the mean obtained

Table V

Central tendency and variability values (degrees) for the acute angle pogonion-nasion-tuberculum

Sex	N	Age 5 years Mean	Age 5 years S.D.	Age 14 years Mean	Age 14 years S.D.
Girls	26	76.4	2.8	80.1	4.2
Boys	22	78.4	4.0	81.9	3.7

on girls is smaller than that obtained on boys. At 5 years a dependable difference is tenable at the 5 per cent level; at 14 years the null hypothesis cannot be rejected.

3. Pooling the data for a given age on both sexes, the obtained means for the angle are 77.4 degrees at age 5 years and 81.0 degrees at age 14 years. It follows that in the 48 children studied the mean increase in pogonion - nasion - tuberculum angle between 5 and 14 years of age is 3.6 degrees.

Comparative reference to radiographic studies by Lande[6] and Bjork[1] is relevant. Lande measured the acute angle formed by drawing lines from gnathion to nasion and from nasion to the center of sella turcica; Bjork measured the acute angle between lines from pogonion to nasion and nasion to the center of sella turcica. The subjects for both investigations were boys.

Lande reports means at ages 3 years and 12 years; Bjork reports means at age 12 years and in early adulthood. In each study, the mean at the older age is 2.8 degrees higher than that at the younger age. Generalizing, findings from Lande, Bjork, and the present study show that over the years from early childhood to early adulthood there is an increase with age in the acute angle between two lines from the region of sella turcica to nasion and from nasion to the region of the anterior margin of the mandible.

Returning to anteroposterior dimensions, it will be recalled that between 5 and 14 years of age the distance from the nasion-pogonion line to the tip of the nose is found to increase much more than the distance from the nasion-pogonion line to the most forward point on the integumental chin (See Table VI, rows 2 and 5). When account is taken of the age change in the pogonion-nasion-tuberculum angle, what may be inferred regarding the forward development of the integumental profile in the lower nasal and chin regions? If the angular increase were due entirely to the movement of pogonion, there would be little difference in amount of forward development of the profile at these two levels. However, it appears unlikely that this extreme assumption with regard to pogonion holds; some downward movement of nasion (See Table 6, row 6) and/or upward movement of tuberculum sella[12] probably occurs. Pelton and Elsasser[19], using a reference line at right angles to the Frankfort horizontal and in contact with the integumental profile near nasion, found that during childhood and adolescence the average North American white boy and girl is characterized by slightly more forward development of the integumental profile in the region of subnasale than in the region of pogonion.

Selected illustrations of individual differences in facial profile. To this juncture, individual variation in the different measures obtained has been denoted numerically in terms of the standard deviation and the Pearson r coefficient of correlation. In the present section, three pairs of profiles are placed in juxtaposition for the purpose of providing pictorial examples of individual variation.

Part A of Figure 2 presents the facial profiles of two children (M 2, F 12) 5 years of age. These children were selected to illustrate the range found for the minimum distance from the nasion-pogonion line to the deepest point of the concavity of the upper lip. The child showing the larger criterion measure (F 12) is *above average** in distance from the nasion pogonion line to the tip of the nose,

Table VI

Central tendency and variability values (mm) representing change in twelve measures of the facial profile over the age period from 5 to 14 years

Measurement	Girls: N = 26 Mean	Girls: N = 26 S.D.	Boys: N = 22 Mean	Boys: N = 22 S.D.
Anteroposterior:				
Level 1*	0.3	0.6	0.5	0.6
Level 2	7.1	1.7	7.5**	2.2
Level 3	1.8	1.4	2.8	1.7
Level 4	0.2	1.3	0.0	1.5
Level 5	1.0	1.1	1.0	1.2
Vertical:				
Nasion to level 1	—0.9	1.8	—1.6	2.7
Level 1 to level 2	9.7	2.4	11.5**	3.7
Level 2 to level 3	4.8	2.0	5.4**	2.2
Level 3 to level 4	1.6	3.0	1.9	3.6
Level 4 to level 5	2.8	2.0	3.0	2.9
Nasion to pogonion	18.8	2.8	20.6	5.2
Angle:				
Pogonion-nasion-tuberculum	3.7	3.9	3.5	2.7

* See first footnote below Table IV.
** N = 20

above average in distance from nasion to pogonion, *average* in distance from the nasion-pogonion line to the anteriormost projection of the chin convexity, *below average* in distance from the nasion-pogonion line to the labiomental groove, and below average in pogonion-nasion-tuberculum angle.

Portrayed in part B of Figure 2 are the facial profiles of two children (F 15, F 38) 14 years of age. Those profiles illustrate the range found for the distance from the nasion-pogonion line to the most forward extension of the integumental chin. The child with the smaller criterion measure (F 38) is *below average* in distances from the nasion-pogonion line to the labiomental groove, the deepest point of the concavity of the upper lip, and the anteriormost point on the convexity of the integumental chin. In pogonion-nasion-tuberculum angle, vertical distance from the root to the tip of the nose, and the remaining distances from the nasion-pogonion line to the facial profile this girl closely approximates the *average*. These findings and those in the preceding paragraph were obtained by referring the measurements on individual children to the appropriate group statistics presented in Tables II, IV and V.

In part C of Figure 2, facial profiles are displayed for the same child (M 38) at ages 5 and 14 years. Of the subjects included in the study, this boy exhibits the greatest change in

* As used throughout this section, "above average" denotes that the child falls more than one standard deviation above the mean of the sex-specific distribution for the variable specified. "Below average" implies "more than one standard deviation below the mean."

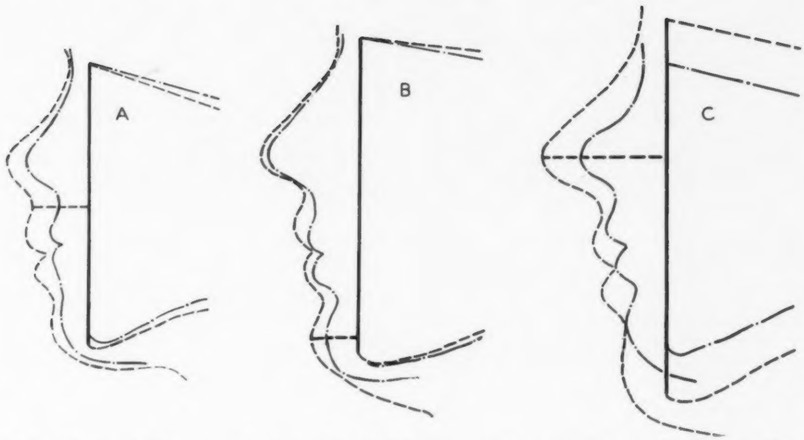

Fig. 2 Selected illustrations of individual differences in integumental profile of the face.

distance from the nasion-pogonion line to the tip of the nose. His increment is almost 60 per cent greater than the mean increment for boys. In other measures the age changes of this boy are *below average* for vertical distance from the tip of the nose to the deepest point of the concavity of the upper lip, *average* for distance from the nasion-pogonion line to the root of the nose, and *above average* for distance from the nasion-pogonion line to the labiomental groove, distance from the nasion-pogonion line to the most forward point on the chin, and vertical distance from the root to the tip of the nose. The group statistics to which the age changes on M 38 were referred are assembled in the right-hand columns of Table VI.

Summary

Early sections of this paper present quantitative procedure for describing the integumental profile of the face and discuss the reliability of data amassed through its use. The procedure necessitates *norma lateralis* radiographs of the head showing good definition of the anterior facial skeleton and the integumental profile. A reference axis is drawn through nasion and pogonion, and from this axis the profile is studied horizontally, vertically and with respect to a cranial-base line.

Later sections of the paper report findings obtained on 48 North American white children each studied at 5 and 14 years of age. Profile variation is investigated for twelve separate measures, with analyses being made for size at age 5 years, change between 5 and 14 years, and size at age 14 years. Associations between aspects of the integumental profile are studied and individual differences in facial profile illustrated.

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Recognition And Interception Of Aberrant Canine Eruption*

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"Eruption" of a tooth has two meanings. Although commonly used to denote appearance in the mouth, each tooth traverses, normally, a well defined path through the maxilla or mandible. This double meaning of tooth eruption has been emphasized by Broadbent[3],[4] by Noyes, Schour and Noyes[8] and by others. Aberrant eruption of the canine tooth means deviation from its usual path during migration from its site of orgin at about the end of the first year of life. This site in the maxilla is immediately above the root ends of the deciduous first molar.[3] As pointed out by Dewel[6], the maxillary canine's path is unusually lengthy in time consumed as well as in distance traversed for assumption of its place in the dental arch.

Numerous references in our literature testify to orthodontic interest in this tooth. Blum[5] has stated the incidence of canine impaction is second only to that of the mandibular third molar and as recently as 1952-53 we find this statement: "The general practitioner should x-ray the entire mouth routinely and be suspicious when the deciduous teeth are retained after the age of twelve or where permanent teeth are missing".[8]

This characteristic preoccupation with impacted canines implies that such developmental problems can not be prevented and partakes of the ignominy of locking the barn door after the horses have entered the corn patch. Recognition of potential canine impactions was implicit in the first reference to "the ugly duckling stages of normal development" in 1930.[1] Here was presented a charting of normal relationships; the roentgenographic technique had been described earlier but published subsequently.[2] Broadbent also emphasized the role of the general dentist in this problem during the Illinois Telephone Extension Program of 1951-52 and illustrated these ugly duckling stages in the manual issued to subscribers.[4]

It is, then, my hope to interest you in the routine serial use of both lateral and posteroanterior head films, prior to appliance intervention, as a means of recognizing these potentialities and intercepting them by dental surgery. I realize that they can be handled by the use of dental x-rays[4] although this usually involves referring the patient. I also realize that one can sometimes recognize symptoms of cuspid aberrancies prior to clinical eruption.

Figure 1 is the frontal view of the plaster casts of a girl nine and one-half years old. Neither dental nor cephalometric x-rays are needed in this instance to alert the orthodontist to the acutely anterior location of the maxillary canines.

At the opposite end of the scale, for contrast, the orthodontist may be confronted with the problem pictured in Figure 2. These plaster reproductions of a boy of almost thirteen years show a total lack of the labial alveolar bulge

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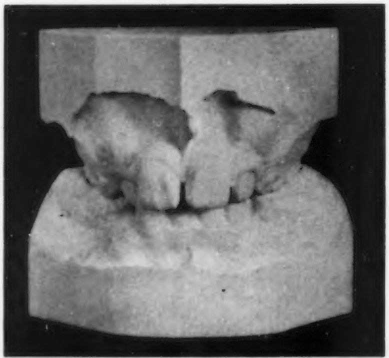

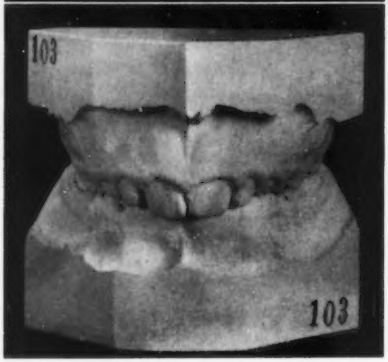

Fig. 1 above, Fig. 2, below.

of the maxillary canines seen in the first illustration. Obviously, there is an acute retardation of this patient's dental maturation and the relationships of the maxillary cuspids need investigation. Roentgenographic examination revealed, among other problems, potential palatal impaction of these teeth; this evidence will be demonstrated later.

In line with Todd's dictum that to recognize the abnormal we must first know the normal, I quote Broadbent's remarks about the "ugly duckling" stages of the developing dentition.

"The shedding of the baby incisors and the eruption of their successors marks the advent of the one very striking example of these ugly duckling stages. This stage when viewed from the frontal aspect - - - - -, after the age of six and one-half years, finds the upper centrals erupting in a relatively short period of time and usually with a separation at the midline. The upper permanent laterals follow and the centrals move together into approximal contact. The growth in lateral dimension of the supporting structures, especially the area at the level just below the floor of the nose where the upper cuspids are developing, is relatively slower, which forces the lateral incisors into a fan-shaped pattern that becomes more pronounced until the time when there has been sufficient gain in lateral growth in the apical base. Coincident with the eruption of the cuspids this lateral dimension increases to permit the more erect position of the incisors".[3]

When one examines a patient in his middle teens who has retained a deciduous cuspid, it means that someone has disregarded the developing dental patterns just described. The next illustration, Fig. 3, depicts the tracing of the frontal x-ray of a boy (W.T.) of almost fifteen years where this has occurred. This clearly shows the succedaneous tooth to be in an unfavorable position relative to the

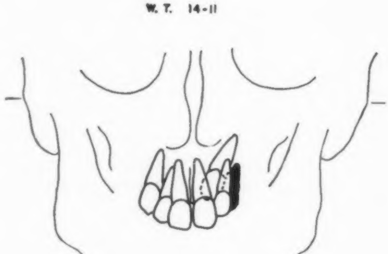

Fig. 3

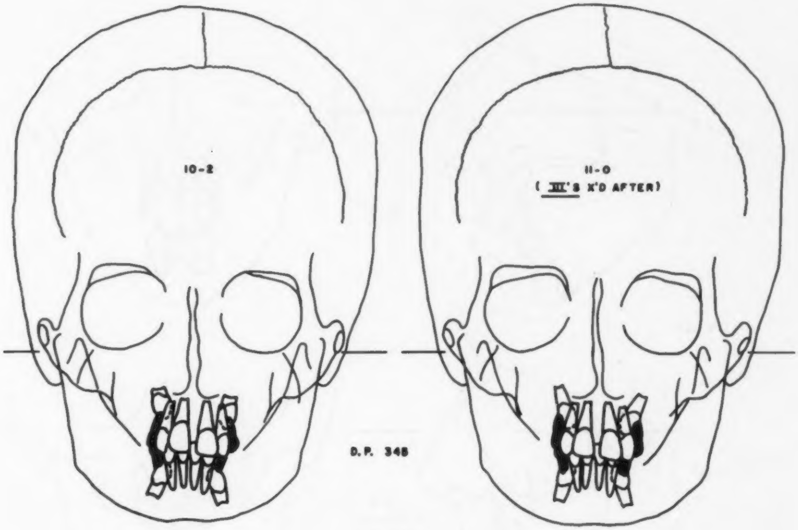

Fig. 4

central and lateral incisors. Immediate removal of the deciduous tooth was advised together with generous removal of alveolar bone[7] to encourage clinical eruption of the permanent canine. Three months after surgical intervention the cuspid was visible clinically although it was lingually positioned. The patient is now under treatment.

This problem could have been avoided with the supervision obtained by patient D. P., Fig. 4. This boy was first seen and clinical records made at the age of ten years and two months. The positions of the permanent maxillary cuspids were considered only a potential problem, relative to his retarded dental development, and a second x-ray examination was advised at about the eleventh birthday. The illustration on the right was traced from the P.-A. film made at that age and indicates further medial tipping of the permanent maxillary canines. Immediate extraction of both primary cuspids and removal of alveolar bone was suggested and followed. This patient was examined a year later when it was seen that the left cuspid was visible in the mouth. The right one was not in sight but was definitely labial as shown by the bulge created between the first premolar and lateral incisor on that side. Through a combination of circumstances this patient was not seen again for more

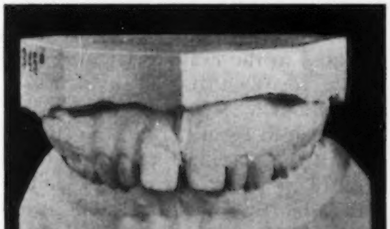

Fig. 5

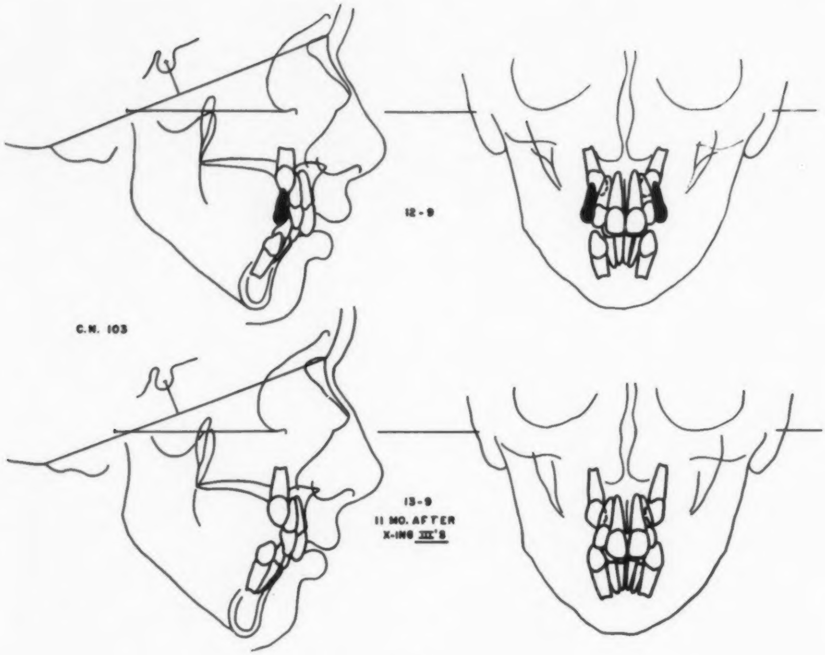

Fig. 6

than two years at which time the plaster records were made which demonstrate a favorable termination for the teeth in question Fig. 5.

It should be noted that the lateral x-ray film provides no guide to these potential impactions. Figure 6 shows tracings of the complementary lateral and posteroanterior x-ray films oriented in the Frankfort Plane. This is the roentgenographic evidence of the patient whose plaster casts, which were seen in Figure 2, gave no clinical sign of the maxillary canine teeth. It is only in the P.-A. image that one can judge the mediolateral positions of the permanent cuspids. In this boy of twelve years and nine months (top row) immediate extraction of the deciduous upper canines was ordered together with generous removal of alveolar bone. A year later, eleven months after the surgery, the tracing of the second lateral film indicates only additional root formation and further descent of the permanent cuspids. In the tracing of the second P.-A. film, however it is obvious that both upper cuspids have reacted favorably: they have moved laterally, are more upright, and thus give assurance that they will eventually assume correct positions in the dental arch.

A similar problem is shown in Figure 7. In this girl of just past eight years both upper lateral incisors had appeared but the lower deciduous laterals were still in place. The upper deciduous right central also remained and had apparently served to deflect the upper permanent centrals. The deciduous upper central

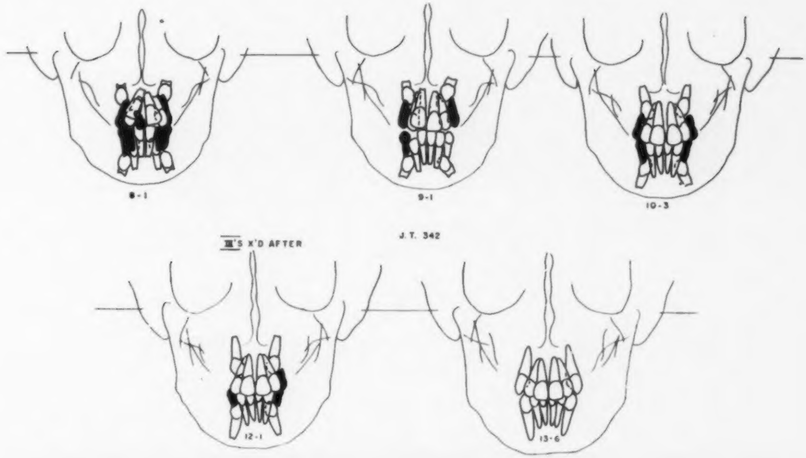

Fig. 7 above, Fig. 8 below.

was exfoliated shortly after this first record and a second set of clinical records was obtained a year later. The tracing of this P.-A. x-ray, taken at nine years and one month, shows improved positions of the eight incisors but medial tipping of the four permanent canine teeth. As already seen in the "ugly duckling" pattern at the nine-year level, this normally is the case but it provides a storm warning for the orthodontist which should not be ignored. A third set of clinical records taken fourteen months later, at the age of ten years and three months, gave further substance to the warning and x-rays were subsequently made at six-month intervals. These also confirmed a significant and progressive retardation in dental maturation. The tracing of the P.-A. film at the twelve year

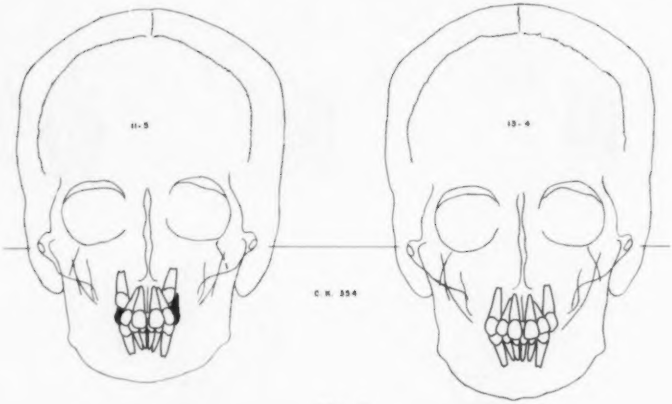

Fig. 9

Fig. 10

and one month stage, combined with the dental x-rays, led me to order extraction of the remaining three deciduous canine teeth. Finally, at the age of thirteen and a half, the four permanent canines were visible clinically and approaching satisfactory positions with the exception of the rotation of that on the lower left side. Figure 8 shows frontal views of the plaster casts at the ages of eight/one, nine/one and thirteen/six.

In this instance the cuspids might have appeared without the roentgenographic supervision and the deciduous extractions. It should be added that between the age of nine years and one month and that of ten years and three months, there was six months of treatment and a short retention period.

It is often difficult to delineate the extent of root absorption on the deciduous canines in either the lateral or posteroanterior film. In the instance of C.K., a girl of eleven years and five months, it was apparent from the P.-A. film that the upper left permanent canine represented a potential impaction, Fig. 9. The den-

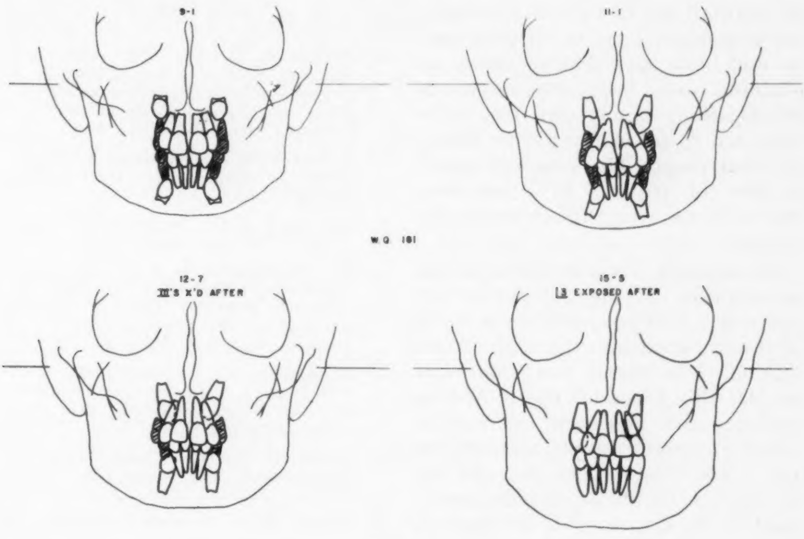

Fig. 11

tal x-rays confirmed that the deciduous upper left cuspid was unfavorably influencing its successor and its extraction was ordered. The patient was examined at six month intervals until both cuspids were well positioned two years later, Fig. 10. Treatment was then started without the tedious effort to position the same tooth required in the instance of patient W. Q., whose frontal tracings are seen in Figure 11.

These show that this program of supervision is not infallible. The first x-rays were made at the age of nine years and one month. In view of the patient's acutely retarded development the positions of the permanent canines were not considered to be a potential hazard. Two years later, however, they were viewed with suspicion and, when compared with their more unfavorable positions at twelve years and seven months, the upper deciduous canines were seen to require extraction. This patient's treatment, for a severe Class II, Div. 1 malocclusion, was started at fourteen and one-half years, after the upper right cuspid had appeared. When he was almost fifteen and a half, the P.-A. x-ray showed impaction of the upper left cuspid. It was surgically exposed and moved to its proper position during the last half of an unduly long period of active treatment covering more than two years. The increasingly oblique positions of the upper canines in the x-rays prior to treatment should have constituted sufficient warning to require free alveolar bone removal rather than simple removal of the deciduous tooth, thus probably avoiding the impaction.

With few exceptions in my experience, potential impaction of permanent canine teeth is seen in patients exhibiting moderate to severe retardation of dental maturation. By that I mean a slow rate of permanent tooth formation as well as retarded exfoliation of the deciduous teeth. It would

be useful, if one had a sufficient number of such problems, to correlate dental and bone ages. The incidence of potential cuspid impactions also needs investigation; in my own case it is estimated to be in the ten to fifteen per cent range. The relatively small number of patients in a one-man office does not attach reliability to this estimate.

In summary, early recognition and interception of potential canine impactions is a highly useful by-product of routine cephalometric x-ray examination. The lateral film alone can not fill this function; the P.-A. film provides the necessary information and may require supplementary dental x-rays. The proper time for removing the deciduous cuspids is modified by the dental age of the patient. When extraction of the deciduous cuspid is ordered, it is often wise to ask for removal of a generous amount of alveolar bone to favorably influence the positions of the aberrant permanent teeth and to encourage their ultimate clinical appearance.

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Developmental Migration Of Mandibular Buccal Dentition In Man*

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INTRODUCTION

It is universally accepted that the facial skeleton is growing during the preadolescent and adolescent years in which orthodontic therapy is usually instituted. An extensive and generally excellent literature reports many of the morphological and mensural aspects of these growth processes. The orthodontist is aware that the growth of this region, in general, and of the maxilla and mandible in particular may greatly influence the clinical end result. It is not so well appreciated that the teeth themselves undergo certain positional changes relative to the bones which support them. This question is at once of basic interest to both the student of cranial morphogenesis and to the clinical orthodontist. The proper application of extrinsic forces to teeth which may then be moving in one or more planes of space *independently* of the movements of their supporting bones requires more than a philosophical acceptance that such movements exist. What is needed is a more precise and quantifiable description of such dental movements.

The present paper reports data on one aspect of these movements; the normal anterior (mesial) migration of the mandibular buccal dentition. The correlation of such movements with the maturational status of the skeleton is noted. Finally, a possible role of these movements in the pathogenesis and treatment of Class II malocclusion is tentatively suggested.

MATERIALS AND METHODS

The mental foramen was the reference point by which tooth movement was judged. It had been established previously that the site of this foramen in the mandibular body was proportionately identical at all ages in man[1, 2]. Tooth position was determined by the relationship of the root apex to the center of the foramen. In dried skulls root position was projected from the crown, while in x-rays of patients position was determined directly. Obviously tilted teeth, or those with curved apices were rejected. The left side was used consistently, both cross-sectional and longitudinal growth study techniques were used.

Cross-sectional data: These consisted of 233 American Indian skulls of all ages from the Department of Physical Anthropology, Harvard University, 118 assorted adult skulls from the Department of Physical Anthropology, American Museum of Natural History, and 37 Macaca mulata and M. rhesus skulls of various ages from the Department of Mammology of the latter in-

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Table 1

Position of mental foramen relative to mandibular dentition (in %) — left side of American Indians

	C	$m_1(P_1)$	m_1-$m_2(P_1$-$P_2)$	$m_2(P_2)$	P_2-M_1	M_1
No Decid. Dent. N=14	71.5	28.5				
Lower Decid. Incisors erupted N=14		100.0				
m_2 not erupted N=9		100.0				
Complete Decid. Dent. erupted N=65		90.8	9.2			
M_1 erupted N=29		38.0	44.8	17.2		
M_1 — $I_{1,2}$ erupted N=36		16.7	44.5	38.8		
M_2 erupted N=23			39.1	60.9		
M_3 erupted N=43			7.0	57.8	25.5	11.7

stitution.

X-rays of dental patients in this institution were obtained in an intraoral film survey of 163 random white patients between the ages of 8 and 18 years (courtesy of Dr. J. A. Cuttita). No attention was paid to the orthodontic status of this group.

Longitudinal data: These were obtained during a three year study of 53 white Class II, Div. 1 patients. At the outset these patients were either untreated or had just had therapy instituted. There were no extractions in any patient and no deciduous teeth were present in either arch. All of these patients were included in a larger longitudinal study of digital epiphyseal fusion[3]. In 38 cases these epiphyses were either unfused or fusion was underway. This group was termed "open" and consisted of 19 males and 19 females with an initial mean age of 12.5 and 11.5 years respectively. In 15 cases digital epiphyseal fusion was complete. This group was termed "fused" and were all female with an initial mean age of 13.5 years. Lateral jaw films were taken periodically in a standardized position, with a mean interval of 9 months. Serial, cephalometrically oriented, lateral skull films were also taken of each patient.

Results

Cross-sectional: Tables 1 and 2 present data of the tooth position relative to the mental foramen in both man and Macaca monkey. In both forms, tooth migration was first noted when the first permanent molars were erupted. The extent of this migration is obviously conditioned by racial and ethnic factors. The random, white, cross-sectional sample of our clinic population (Table 3) shows a more retrusive position of the mandibular buccal dentition when compared with the other samples listed in Table 4 and with the corresponding data in Table 1.

Table 2

Position of mental foramen relative to mandibular dentition in *Macaca Monkey*

	C-m_1	$m_1(P_1)$	m_1-$m_2(P_1$-$P_2)$	$m_2(P_2)$	m_2-$M_1(P_2$-$M_1)$	M_1	No.
Fetal	1						1
m_2 erupting		1					1
Complete decid. dent.	1	6					7
M_1 erupted	1	5	3				9
M_1-I_1 erupted			1				1
M_2 present				6			6
M_2-C present				1			1
M_3 present				4	3	4	11
No.	3	12	4	11	3	4	37

Table 3

Position of mental foramen relative to mandibular dentition in whites (8-18 years).

Data derived from intraoral x-rays

Age	P_1	P_1-P_2	P_2	P_2-M_1
8 N=7	2	3	2	—
9 N=15	2	12	1	—
10 N=14	3	10	1	—
11 N=15	3	11	1	—
12 N=10	2	7	1	—
13 N=18	1	15	2	—
14 N=19	0	14	4	1
15 N=24	3	14	7	—
16 N=18	0	14	4	—
17 N=13	0	9	4	—
18 N=10	1	7	2	—
Total N=163	17	116	29	1
Total Percent	10.4	71.2	17.8	0.6

Table 4
The position of the mental foramen relative to mandibular teeth (in %)

Author	P_1	P_1-P_2	P_2	P_2-M_1	M_1	No.
della Serra[1]	0.5	33.0	58.5	6.5	2.0	100
Tebo[2]	1.8	23.0	49.9	24.1	1.2	100
Moss[3]	.6	27.1	50.8	19.3	2.2	184
Moss[4]				100.0		31

[1]Brazilian adults (Topographia do canal mandibular. 1-114. S. Paulo 1945)
[2]Unselected adults (Dent. Items Inter., 73: 52-53,1951)
[3]Random adult sample from the American Museum of Natural History.
[4]Australian Aboriginal adult mandibles from the same institution.

Longitudinal

Dental migration relative to the mental foramen was observed in 17 of the 38 open cases (8 males and 9 females) and in none of the 15 fused cases (Table 5). In these 17 cases, 15 demonstrated movement equivalent of one half a premolar tooth width and 2 cases demonstrated movement equivalent to the width of a complete premolar tooth. The mean age at which the dental migration occurred was 14.0 years for the males and 12.0 years for the females.

Epiphyseal fusion was not completed in any of the 17 open cases which migrated during the course of the study and was observed in only two of the 21 open cases which showed no migration. It is apparent that the 36 open and fused cases in which no dental migration was observed had already completed those movements prior to the inception of the study

Table 5

Position of mental foramen relative to mandibular dentition of orthodontic patients.*

Source of material—lateral jaw x-rays

	Mean age years		P_1	P_1-P_2	P_2
Shift cases—open					
8 males	13.0 (M)		14	3	0
9 females N=17	11.5 (F)	initial			
	14.0 (M)		0	12	5
	12.0 (F)	final			
No Shift—open					
11 males	12.1 (M)		6	13	2
10 females N=21	11.8 (F)	initial			
No Shift—fused					
15 females N=15	13.5 (F)	initial	3	8	4

* In this table "shift cases" are those showing dental migration, "open" refers to epiphyseal status. Initial age is age of first x-ray, while final age is that at which a film first demonstrated the shift.

(Table 5).

The reality of these movements had been preliminarily confirmed by animal experimentation. In two Green monkeys with metallic mandibular implants similar absolute dental migration has been observed. These data will be published elsewhere.

Discussion

Human fetal studies substantiate the initial position of the mental foramen. At the third fetal month the usual location is between the developing follicles of the deciduous cuspid and the first deciduous molar[4, 5]. Our data make it clear that no essential anterior motion of the teeth occurs until the deciduous dentition is complete, in both man and monkey.

The alteration of the position of the mental foramen relative to the mandibular buccal dentition is unquestioned. The use of this foramen as a fixed point for measurement is justified in the following way. Let us divide the mandibular body into two horizontal chords, one extending from the mandibular foramen to the mental foramen and the other from the mental foramen to the mid-line of the mental symphysis, with the mandible held in a constant position[6], in a series of mandibles of various ages. We measure the two chords as well as the transverse distance between the two mental foramina. We then determine the percentage of the whole that each chord forms. We may, alternately, plot these data on log paper and demonstrate their allometric relationships. Either way it will be found that throughout the growth of the mandible the mental foramen maintains a constant relationship. In Figure 1 the anterior segment is constantly 32% of total horizontal length. It is clear in this figure that the increase of anterior chord length is easily accounted for by the lateral increase in interforaminal width alone, without recourse to any posterior movement of the foramen. Obviously the data presently reported indicate an absolute anterior migration of the buccal teeth through the alveolar bone.

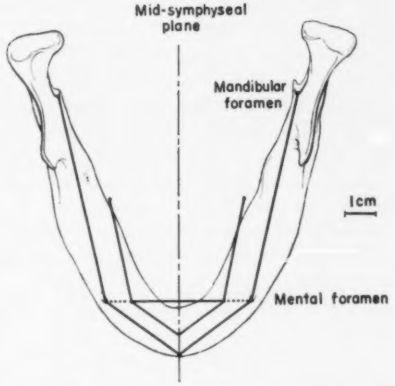

Fig. 1 An occlusal view of a human adult mandible with the dentition omitted. Two chords are shown, the anterior connecting the mid-symphyseal point with the mental foramen, the posterior connecting the mental and mandibular foramina. The inner chords illustrate identical relationships in a circumnatal mandible (anterior chord is 32% of total length). The transverse distance between the mental foramina is also shown. The dimensions of these chords and of the transverse diameter represent mean values of groups of North American Indian mandibles, adult and circumnatal, gathered at one pueblo (Canyon del Muerto, Arizona). The dimensional increases in chord and transverse lengths are proportional. The relative constancy of the site of the mental foramen is illustrated.

Substantial support for our hypothesis is obtained from the literature. Studies by Friel[7] in both man and lower primates, of Clinch[8] and Bonnar[9] in man have established that the initiation of this movement occurs between the completion of the deciduous and the onset of the permanent dentition. They show further that these movements are not due to a mere "drifting" of teeth to close interproximal spaces. On the contrary, it is quite

clear that both maxillary and mandibular buccal segments move as a whole, often independently of each other and without necessary bilateral simultaneity. Whatever objections might have been raised in the part of the work of these authors, among others, on the ground of a lack of a fixed reference point would appear to be obviated by our present study. Similar movements of maxillary buccal teeth alone has been reported by Lysell[10] using the palatine rugae as a reference site.

The histological basis for the bodily movement of teeth through bone is quite firm. The data of Schwartz[11], Stein and Weinmann[12], and of Weinmann[13] have definitively established the simultaneous sequences of mesial osseous resorption and distal osseous apposition in buccal dental segments. Recently a homologous sequence was histologically established for the migration of the anterior teeth[14].

While the reality of these movements is still a matter of discussion in some orthodontic circles, with pros and cons vigorously held[15, 16] biological thought on the matter is best summarized by Brash[17] who states "forward movement of the cheek-teeth in the alveolar bone is a fundamental phenomenon of the growth of the mammalian jaws".

Class II Malocclusion

Our longitudinal data clearly demonstrated the final stages of dental migration in the 17 open cases. These same data, in addition, also showed that a Class II malocclusion is not *necessarily* related to dental migration or the lack of it. Certainly in the 21 open cases and in the 15 fused cases, in which the dental shift had already occurred, the malocclusion prior to treatment was no less real than in the 17 cases in which the buccal segments had not yet completed their movement. The possibility remains that in these 17 cases a premature cessation of normal dental migration was etiologically significant. That tooth position alone differentiated these Class II cases was substantiated by tracings of the morphologic contours of the skull base[18] and of the facial skeleton obtained from the cephalometric films. These failed to reveal any difference between the several Class II subgroups. No sex differences were noted.

Dental migration occurred in our 17 cases during therapy. It is interesting to speculate as to the effect the lack of therapy might have had on the migration of teeth in these patients. The type of therapy had no apparent relationship to movement. In these 17 cases molar relationships became normal when dental migration was completed. In the remaining cases clinical correction occurred without further mandibular dental migration. The concept of correction through migration, in some cases, supports the views of Sleichter[19]. The possibility that the *maxillary* buccal dentition has migrated anteriorly more than normal in the remaining Class II cases raises interesting aspects worthy of further research.

The dichotomous classification of our longitudinal series into open and fused groups was clinically justified. Examination of the clinical progress notes invariably showed that treatment was at once more rapid and satisfactory in the open group, while in the fused group progress was slow and difficult at best.

In essence we were able to observe dental migration during therapy in a group of patients whose digital epiphyses were unfused. These patients were not younger than those similarly maloccluded in which dental migration had already occurred and whose digital epiphyses were also unfused. In the concurrent study of

digital epiphyseal fusion[3], a quantitative measure of the rate of skeletal maturation was derived. On the average our present 17 cases demonstrating a delayed shift were characterized by a *slow* rate of digital epiphyseal fusion (i. e., they took about twice as long to fuse a given digital epiphysis as did a *fast* group). It has been established that the maturational status of the hand is a good indicator of general skeletal maturity[20]. Seemingly, dental migration is correlated in some manner with the rate of skeletal maturation as a whole.

Summary

1. A longitudinal roentgenographic study of white Class II, Div. 1 adolescents was made.
2. The position of the mandibular buccal dentiton was studied relative to the mental foramen. The position of this foramen was shown to be proportionately constant at all ages. The longitudinal data were compared with several cross-sectional studies.
3. In 17 cases an absolute mesial migration of these teeth was observed. This was shown to be the completion of a normal, physiological movement.
4. An additional 36 cases did not show such migration, as it had been completed prior to the inception of this study.
5. The status of digital epiphyseal fusion was used as an index of skeletal maturation. The dental migration occurred prior to the completion of this fusion.
6. It appeared that dental migration was completed more rapidly in cases whose rates of skeletal maturation were similarly more rapid.
7. The role of dental migration in the etiology and treatment of this type of malocclusion was discussed.

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Theoretical Mechanics And Practical Orthodontics*

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INTRODUCTION

Contemporary education, receiving its nutrients from basic research, continually refutes any policy of isolationism of the separate disciplines. While the boundaries between the basic sciences, at least by definition, may be sharp and definitive, any comprehensive research demands an interplay of bodies of knowledge—a synthesis of disciplines. The complexity of the problems of the physical world, just as those of the social, encourages a breakdown of isolationism. Particularly in the biological sciences is the multidisciplined approach becoming necessarily apparent. The biochemical marriage is a most solid and enduring one. The nuptial vows of biophysics are more recent.

As Rashevsky suggests, "application of mathematics to special biological problems is not new, but a systematic mathematical biology is timely. It is not now possible to 'explain away' phenomena of life in terms of physics, but this approach may be developed in the future. Since biological phenomena are closely related to physical phenomena,—there is a desire to unify all natural sciences."

The attempt at explaining the origin of life from non-living things seems nearer reality. Urey's classical work of the production of amino acids by subjecting certain simple gases to electrical discharge suggests a rapport between the viable and the nonviable—a unification of natural sciences.

To those disciples of practicality and office efficiency, it is acknowledged that purely theoretical hypothesizing may not have immediate practical interest of even urgent direct application to some experimental set-up, let alone positive correlation to this year's income. However, the history of physics reveals that pure theoretical developments led decades later to most astonishing practical results. Today's eminently useful duality of the benison and cataclysm of atomic fission are some years removed from the theoretical dreamings of Bohr and Einstein. More pragmatically, Gottlieb suggests: "The results of today's research is destined to be an integral part of the practitioner's work of tomorrow."

In contemporary orthodontics, a unique situation attains in that the dentist must of necessity combine his knowledge of the problems, sciences, and techniques of general dentistry with sciences usually considered tangential to his field—such disciplines as embryology, growth and development, anthropology, biochemistry, and particularly the science of force action-mechanics.

These additional disciplines are applicable to orthodontics, not in the segregated sense, but as important in-

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tegrated parts of the whole. It is principally with the science of mechanics and the importance of its application to orthodontics that this paper is concerned.

The physiological reactions which permit the movement of a tooth through its bony environment cannot be fully understood independent of a concomitant understanding of the actions of the initiating forces. Because of the classical work of Oppenheim, Sandstedt, Moyers, Storey, etc., some significant information is now available concerning the biological changes occurring during tooth movement. Though the mechanism of tooth movement is basically biological, it is initiated by force action and, until such time as teeth can be moved by injections or internal medication, the orthodontist will be vitally concerned with mechanics.

Sicher, whose impact on the biology of orthodontics has been significant, feels that in our contemporary attempts to surplant the early "mechanistic" or gadget approach by a more scientific biological one, we have tended to forget the pure physics.

Furthermore, research into the true nature of the biological mechanism of tooth movement is fruitless without a parallel understanding of the force action involved. Within the next decade, biophysical research in the field of orthodontics should answer a number of important questions, some of which might be:

1. What is the quantitative relationship between rate of tooth movement through its bony environment and the reactive pressures on the tooth root?
2. What part is played by the musculature and the geometry of the supporting bony structure in establishing positional stability of the dentition?
3. Can muscle tonus, i.e., the force which it exerts, be changed to accommodate new positions of stability of the teeth?
4. What is the relationship of pressure and the immediate deformation of the periodontal ligament?
5. Can growth of bone tissue be retarded by mechanical means?

The Importance of the Concept of Equilibrium

The principle of equilibrium is manifest in many branches of science, physical and biological. All bodies are in equilibrium with their surroundings. Equilibrium controls the behavior of the stars in the heaven and the fish in the seas. The motion of the planets of the solar system and the motion of the electrons of the atom are manifestations of the same principle. The universality of the concept of equilibrium is such that the fact that teeth are in equilibrium with their surrounding environment cannot be questioned. The equilibrium with which orthodontics is primarily concerned is the static equilibrium of forces. In order that the body, in this case a tooth, be in static equilibrium, two conditions must be satisfied: 1. The vector sum of *all* forces acting on the tooth must equal zero, 2. the vector sum of *all* moments of forces acting on the tooth relative to any point must also be zero. Forces which may act on the teeth include those applied directly by the surrounding musculature, forces due to natural functions, such as mastication, forces due to pernicious habits, forces due to the presence of orthodontic appliances, and the *reactive* forces applied to the roots of the teeth by the surrounding bony structure through the periodontal ligament.

From the standpoint of the orthodontist, the idea of equilibrium of the

tooth can be further analyzed. In line with the above hypothesis, it is obvious that the tooth must be in equilibrium at any particular instant. However, it may not be so self-evident that the teeth must also be in a mean state of equilibrium extending over a considerable period of time. Over such a period the effects of short term random forces can be expected to nullify each other so that the resultant tooth movement would be zero.

Resultant forces of long duration and repeated application enter into the mean equilibrium picture and under ordinary circumstances cause movement of the teeth. A resultant force in this case may be described as a sort of net force. For instance, a premolar subjected to a .1 oz. force exerted by the buccinator musculature and simultaneously subjected to, say, a .3 oz. force exerted by the tongue could be said to be subjected to a .2 oz. force exerted by the tongue and directed buccally. As long as the crown of a tooth is acted upon by a long term resultant force, the mean equilibrium of the tooth must be accomplished by the development of reactions exerted on the root through the periodontal ligament. Such reactive forces are the initiators of biological actions which culminate in tooth movement.

It must be emphasized that duration of application, as well as the vector properties of force, is important in determination of the mean state of equilibrium. It may be hypothesized that the product of force magnitude and time controls the rate of tooth movement.

Stability

An additional area of theoretical mechanics which is of great importance to the orthodontist is stability. The orthodontist is concerned with the movement of teeth from positions of malocclusion to positions of good occlusion, but he should be concerned further with the stability of the teeth in their new positions. Putting the teeth into new positions of instantaneous static equilibrium is not enough. These positions must be ones of *stable* static equilibrium so that the teeth will not tend to drift back to their old positions of malocclusion or to new positions of malocclusion with the passage of time.

In general, a stable position is one to which a body will return readily and of its own accord if subjected to minor displacement. That is, the minor displacement referred to will cause the body to be subjected to forces which will dictate a return to its original position. If, however, the minor displacement causes the body to be subjected to forces tending to further increase the displacement, the body is said to be in an unstable equilibrium position.

Stability must consider the origin of some of the forces that act upon the teeth as previously mentioned, i.e., those forces emanating from the musculature, natural functions, or pernicious habits. These are the forces which must dictate whether or not a tooth is in a stable position. It should be noted that these forces do not include those exerted by the appliance, since consideration of these appliance forces could be justified only if the patient were to wear some sort of retentive device indefinitely.

Fischer points out, in connection with hazards of treatment, that "the stability of the denture in malocclusion is the result of the very same forces that will be responsible for the final positioning of the teeth after treatment."

Purely from the standpoint of mechanics, stable positions of equilibrium are always positions in which the ener-

gy stored in the system is a minimum. Since the laws of mechanics are applicable to the teeth individually and to the dentition as a whole, it must be concluded that stable positions of the dentition and its elements are positions in which the energy stored in the system is minimal. Here the system in which energy is stored must be considered to be the teeth, the pertinent bone structure, and particularly, the surrounding musculature. In some instances there may be but one stable location for a tooth or segment of the dentition, but in many circumstances there may be multiple positions in which stability will be achieved. An example of such multiple positions of stability would be molar crossbite. The maloccluded position is stable, since there is no tendency for the tooth to move from this position or to correct itself. This malocclusion represents one of several energy minima. When this crossbite is corrected orthodontically, a new position of minimum energy is achieved and the result is also stable.

Relapse of the treated dentition indicates that the teeth were left in unstable positions at the conclusion of treatment. Stability of the dentition need not imply that the teeth are stationary, since growth may present a changing set of conditions to which the teeth become adapted by appropriate movements. It can, however, be categorically stated that every relapse is the end result of instability.

Mechanics of Materials

Another subdivision of mechanics with important ramifications in orthodontics is that of the mechanics of materials. Where mechanics as a whole is concerned with the forces of motions, mechanics of materials, in particular, is concerned with stresses, strains, and deformations. Since orthodontic forces are exerted through the medium of fabricated appliances, it is necessarily apparent that a knowledge of the mechanical properties of the materials involved is most essential. Each appliance as constructed by the orthodontist has certain essential mechanical characteristics, such as strength, stiffness, and resilience (energy storage capacity). These properties of the appliance are dependent upon the intrinsic properties of the material, strength, stiffness, hardness, and resilience, as well as the extrinsic properties characteristic of the appliance design, such as shape and size. Important quantitative characteristics of the appliance are dictated by the laws of mechanics of materials, and are of direct concern in that they control the magnitude of the forces exerted by the appliance, the deformation of the appliance, and the rate at which force will be dissipated. Since these properties govern the basic mechanics of the appliance they are of utmost importance for a thorough understanding of this essential tool.

Summary

1. Scientific orthodontics requires a multidisciplined approach. No single branch of basic science can be sufficient support for its complete understanding.

2. Of particular importance to orthodontics is the science of theoretical mechanics- the science of force action. Unfortunately, most graduate students in orthodontics are not sufficiently prepared in this area by their undergraduate or professional training.

3. The importance of an understanding of force action should be self-evident in view of the fact that force must be relied upon to initiate biological reaction in the movement of teeth.

4. The concept of equilibrium is essential to an understanding of the forces acting upon individual teeth

or upon segments of the dentition. Such forces must include not only those acting upon the crowns but also the reactions upon the roots.

5. Since one of the criteria of successful treatment is the absence of relapse, stability is of primary concern in orthodontic therapy. Theoretical mechanics is the key to understanding and recognizing the characteristics of stable and unstable conditions.

6. The application of orthodontic forces through fabricated appliances makes essential an understanding of the mechanical properties of the materials of which these appliances are made. Mechanics of materials is the discipline embodying such knowledge.

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Principles For Use Of The Edgewise Bracket With Rotation Arms

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There has been little question among those who are adept with the edgewise orthodontic bracket that it is one of the most efficient attachments yet designed for the correction of malocclusion of teeth. Technically its scope is broad. It is possible to move teeth in any direction with round and rectangular archwires when they are used in conjunction with the edgewise bracket.

There is, however, one weakness in this mechanism as it has been used. It is the difficulty encountered in the correction of rotated teeth. Slight or severe tooth rotations are a problem to correct and, secondly, are a problem to maintain in their new positions after the correction. Staples are generally soldered or welded on the mesial and distal of each band in strategic positions from second bicuspid to second bicuspid for the purpose of applying leverage against the bracket for rotation movements. Ligatures running through these staples and ligated to the archwire slowly and gradually correct the rotation of the teeth after repeated activations.

This procedure is generally slow and can be painful to the patient. The tightening of the steel ligatures passing through the staples and then twisted tightly around the archwire frequently causes sudden tension, blanching of the tissues, and pain.

When threading ligatures through staples, it will often be found that the steel ligatures are quite loose even before the patient leaves the office. This seems to indicate that sometimes little has been accomplished by this method in the correction of these rotated teeth. Who has not forgotten to replace rotation ligatures when retieing an archwire and then, at a later appointment, find one or more teeth resuming their one time rotated positions? How often have you threaded a ligature and had the staple tear away from the band?

Many attempts have been made to overcome this weakness of the edgewise bracket. The most successful it seems now is the combination of the bracket and two rotation arms extending laterally from the bracket itself.

When the archwire, round or rectangular, is seated in the brackets and the teeth are in their relatively correct positions in the dental arch, the archwire rests not only in the bracket slots, but also on both edges of the rotation arms. Thus, instead of one, there are three points of contact possible with the archwire for each band with the application of a single ligature.

In cases where there are several severely rotated teeth, it is not always possible or advisable to fully seat a starting .016 archwire into each bracket the first time (Fig. 1). The archwire may be ligated into most of the brackets but only pulled close to

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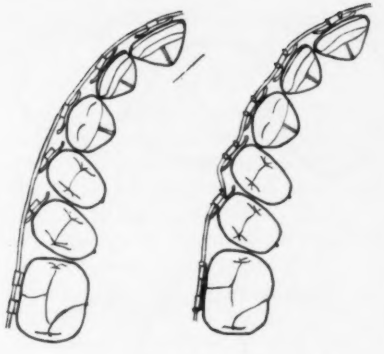


Fig. 1

or partially seated into others. The archwire generally rests against only one of the rotating arms on each rotated tooth and, when the steel ligature pulls the small round archwire into the bracket, the prominent portion of the rotated tooth is gently pushed into its correct position through the spring and resiliency of the archwire acting on the prominent rotation arm. Thus a gentle pull and push action starts the correction of rotated teeth.

In most cases after an appointment or two it is possible for each tooth to have the above mentioned three points of contact with the small round archwire.

It is quite obvious that this makes the use of staples unnecessary thus eliminating the time necessary for the soldering of two on each band. More important, however, is the elimination of the time consuming operation of tieing and retieing ligatures through staples on each rotated tooth. Simple ligature ties securing the archwire in each bracket are all that is necessary for each tooth when rotation arms are used.

Rotation

The bracket with rotation arms, while very efficient for rotated teeth, can be used as effectively on nonrotated teeth as well. Greater control for each tooth by virtue of the three points of contact with the archwire means increased stability. Each nonrotated tooth with its bracket and two rotation arms in contact with the archwire assists in the correction of adjoining rotated teeth and their maintenance.

Maintenance of corrected position is especially necessary and important in the case of the mandibular incisors when they are put under strain as when Class II elastic traction is being used. These incisors do not twist or turn during the time that elastics are being worn, but are easily maintained in straight alignment because of the constant three points of contact with the rectangular archwire.

It has always been good judgment to use small round starting archwires in most of our cases after the bands have been cemented. It is a more physiologic action in relationship to both hard and soft tissues to get bracket engagement and start the levelling procedure with these small round wires, and is certainly less painful to the patient. This is also ideal for the correction of rotations. Rotated teeth respond quickly and, in many instances, without pain or annoyance to the patient when a little care is exercised in forming these starting archwires. Often the patient is not aware that correction or rotations are being accomplished and, only when shown the original casts, do they realize the change that is taking place.

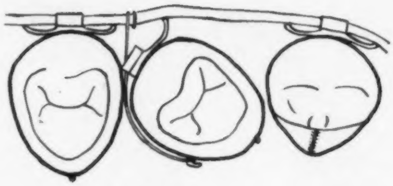
It is easy to realize that the most successful corrections of rotated teeth are those that are accomplished very early in treatment. When rotation arms are used and rotations are corrected, the once irregular teeth are never allowed to return to their former

malpositions in the dental arch. The longer the rotated tooth is maintained in a corrected position, the less difficulty is encountered in its retention.

Cases in which extreme rotations must be corrected have always been a hazard to successful treatment and retention. Often these cases have proven a disappointment because such teeth proved mechanically difficult to rotate and just as difficult to maintain during and after treatment. A partial return to their former positions seemed almost inevitable unless a constant vigil was kept by always maintaining tension on these teeth by ligatures through staples. Rotated bicuspids and cuspids, as well as anteriors, fall into this category and occur in one or both arches.

Overrotation or, more accurately, overcorrection of rotated teeth has been mentioned many times in the past, but only now do we have a simple technic and an efficient instrument to actually and efficiently overcorrect the once badly rotated tooth. With a pair of pliers either rotation arm may be bent outward just enough farther so that, when the light round archwire is drawn into the bracket by the ligature, the prominent rotation arm is pushed away from the archwire, thus actually overcorrecting the once rotated tooth.

Whenever possible on the average rotation, the bracket is placed ideally in the middle third of the tooth mesiodistally. In cases of extreme rotation it may be impossible to use both rotation arms, in which case one of them is cut off close to the bracket before the band is cemented. The remaining arm is bent out so it is a more prominent fulcrum when the bracket is ligated; sometimes it will help to notch the edge of the rotation arm slightly to receive the round archwire. A spur soldered on the lingual of the band



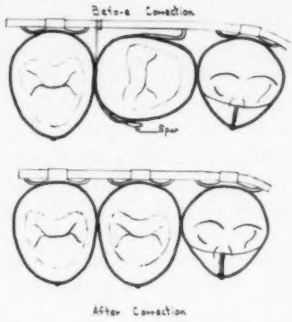


Fig. 2 above, Fig. 3 below.

from which a ligature can be applied is very effective in the early stages of correction, Fig. 2.

On occasion, the rotation will be so extreme that the archwire cannot be ligated into the bracket for an appointment or two and a ligature from the lingual spur to the archwire starts the rotation with the notched arm acting as a fulcrum against the archwire. As soon as the bracket is available for ligation, the lingual spur is no longer necessary. At a later appointment a new band with rotation arms may be made and cemented.

There are, in fact, instances in which no bracket at all can be used at first, due to the extreme rotation of the tooth, Fig. 3. A plain band is made with a lingual spur and a notched rotating arm to serve as a fulcrum. After the rotation is partially corrected through the action of the ligature and the archwire on the ful-

crum, the band is removed, a bracket ideally placed, and the correction completed. Fortunately these latter instances are not too common.

Parallel Roots

Certainly one of the most valuable assets of the bracket and, possibly, one that is least understood, is the ability to control the tipping of teeth. An individual tooth or group of teeth can be prevented from tipping by and through the use of spurs. Spurs strategically soldered on the rotation arms prevent the undesirable tipping of some teeth during orthodontic movement and on other teeth can cause desirable tipping when needed.

Canines and premolars in both jaws, but particularly in the mandible, often tip undesirably during space closure in extraction cases. Who hasn't struggled with these teeth to maintain them in a somewhat upright position and failed by several degrees to finish with parallel roots of the teeth on either side of the extraction spaces at the end of treatment.

Just how important are parallel teeth and roots for our patients? What if lower canines do tip distally 6 degrees, and second premolars tip forward a similar amount? Is this dangerous? Will they straighten up eventually? If you are lucky, these mandibular teeth will straighten up by themselves, but there most probably will be a large open contact between the canines and second premolars. Well, that is better, one might argue, than a slightly loose contact. That is true, but what about the resultant occlusion where large open contacts exist? If the occlusion allows the canines and premolars to straighten up, is not one apt to complete treatment with premolars and molars in an end to end relationship instead of the cusps in correct occlusion?

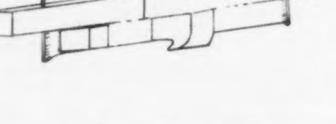
Suppose we are unlucky and the mandibular canines and premolars do not come out of their tipped positions? Periodontists tell us that the "V" area caused by the tipping of two teeth creates a food trap which ultimately may cause periodontal breakdown. Orthodontically, too, tipped teeth in the mandibular arch can easily lead to an increase of the curve of Spee and a return of a deep overbite.

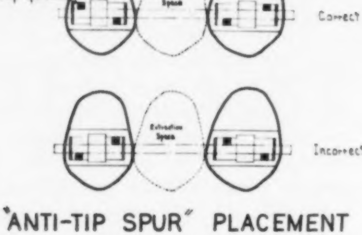
Anti-tip Spurs

In extraction cases anti-tip spurs soldered on the rotation arms of canine bands gingivally to the archwire on the mesial, and occlusally on the distal, prevent these teeth from tipping as they are being moved distally. Likewise, on the premolar bands, spurs soldered gingivally on the distal and occlusally to the archwire on the mesial, assist in keeping these teeth from tipping in the closure of spaces. Over the past ten years this has been proven a countless number of times with good results when this technic is followed.

The technic for soldering on these spurs is as follows: After the band has been formed and soldered, a small pellet of solder is fused on the surfaces of both rotation arms near their terminal ends. A piece of round or rectangular gold wire is soldered at right angles to each rotation arm at the spots where the solder was previously placed. The gold wires are cut off and smoothed flush with the archwire, forming spurs, one gingivally, and the other occlusally, Fig. 4.

There are several ways to solder on these spurs; perhaps the easiest way is to ligate a short section of .022 x .028 stainless steel wire snugly into the bracket. The spurs can then be soldered accurately onto the rotation arms and flush with the stainless steel section. Spurs can be positioned, after a little practice, almost as easily as staples are soldered.





"ANTI-TIP SPUR" PLACEMENT

Fig. 4 above, Fig. 5 below.

Anti-tip spurs, as their name implies, when properly placed on the rotation arms prevent the tipping of premolars and canines as they are being moved in extraction cases, Fig. 5. Mechanically the spurs greatly increase the leverage action of the archwire thus enhancing the success of bodily movement of these teeth. The rotation arms correct and/or prevent the undesirable rotations; the spurs soldered on the arms act as brakes or controls as the teeth are moved along the archwire. When the extraction space is closed between the canine and premolar, the spurs continue to hold these adjoining teeth in parallel positions. At any time the spurs can be clipped off and smoothed down if desired.

We all have cases, now and again, in which canines originally present distal axial inclinations and second premolars, particularly the lowers, may also exhibit marked mesial axial inclinations, Fig. 6. The small round starting archwires are very effective in correcting this undesirable tipping when anti-tip spurs are used as described. The spurs vastly increase the leverage action of the starting round archwire in uprighting initially-tipped canines and premolars. The application of these spurs is obviously not limited to extraction cases alone.

Spurs soldered on rotation arms have another function only mentioned so far. It is the ability to start or initiate the tipping of a tooth or a group of teeth when and where desired. I refer to the normal artistic tipping or positioning of maxillary lateral incisors by means of spurs, tip spurs in fact, soldered on the mesial rotation arms of these two bands. Fig. 7. The spurs are usually soldered on the mesial arms so that they are in contact with the rectangular archwire when it is seated in the incisor brackets.

Thus only very slight artistic bends

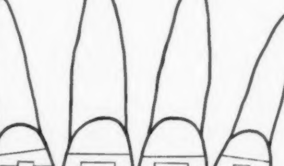


Fig. 6 above, Fig. 7 below.

are necessary in the archwire to move the central and lateral root apices away from each other. Generally, however, these bends are not needed. The spurs on the lateral bands at times are actually anti-tip in character because they prevent the central and lateral crowns from tipping away from each other and, at the same time, stop their root apices from tipping toward one another. It is still a good idea to ligate these four teeth together to prevent diastemas from occurring.

These spurs are especially effective in correcting perverted axial inclinations of the maxillary centrals and laterals. Often extreme tipping of these teeth presents quite a problem in correction. The starting round archwires, acting on these spurs, initiate ideal or normal tipping of malinclined incisors early in treatment. Later, when a rectangular archwire is used, the desirable tipping is continued. In some instances these spurs can be used on lower incisors as well.

Controlling Anterior Axial Inclination

Double width brackets with two rotation arms for maxillary central incisors also are very effective on these two upper teeth. Lingual root torque, so necessary for most maxillary centrals, is more easily accomplished with the double width brackets, while the rotation arms further add to the efficiency of the bracket as has been described.

It was stated earlier that it is highly desirable in most cases to start tooth movement with light round resilient archwires. Bracket engagement, leveling and first steps in the correction of rotations are begun after the first archwire is placed. If possible, all rotations are completed with the .016, .018, or .020 round archwires. Lest anyone think, however, that round archwires are overly favored in the treatment of our cases, it should be stated clearly that rectangular archwires are used just as early in treatment as is feasible in all cases. Greater control in every direction is possible with the rectangular wire after rotations, bracket control, and initial leveling have been effected.

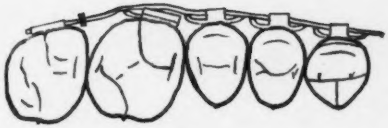


Fig. 8.

Maxillary six-year molars often rotate unfavorably and the correction of these rotations is essential to the normal positioning of the maxillary buccal teeth during treatment and for successful retention. This correction is quite easily accomplished through the use of the double width molar bracket which has one rotation arm. The terminal end of the rotation arm is a fulcrum and, when the starting round archwire is ligated into the bracket, correction of the rotation is easily accomplished. The mesiobuccal cusp is pulled bucally and the distobuccal cusp pushed lingually, Fig. 8. When the correction is completed, the molar can never rotate adversely as long as the bracket is ligated to the archwire.

Another important feature of the rotation arms should be mentioned. It has to do with the temporary reduction or bending away of one arm on the prominent edge of a rotated tooth so that a starting archwire will not be too prominent on extremely rotated maxillary incisors when ligated.

This bending away of the rotation arm is done at the time the starting round archwire is first placed and

makes bracket engagement much simpler at this first appointment. After initial tooth movement has taken place, the rotation arm is gradually bent out again. The ability to reduce or increase the prominence of either rotation arm further increases the use, flexibility and the efficiency of this bracket.

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The author should submit the original typed copy of the manuscript, double-spaced on bond paper. The author's name and city of residence should appear immediately after the title, and the street address should appear at the end of the article.

Do not use symbols to indicate teeth; in *tables* teeth may be designated as U-1 or L-6, but in the text names of teeth should be fully written out.

Line drawings should be prepared in India ink on white stock; the width of lines and the size of lettering should take into account the fact that most illustrations are reduced in size in the engraving process. Photographs should be sharp, glossy prints of adequate size, *unmounted and kept separate from the text.* At the discretion of the editor, illustrations will be reproduced either as single column cuts of approximately 2¼ inches in width, or as double column cuts of 4¾ inches in width. The height of the cut may vary, but contributors should keep in mind that proportionate reduction or enlargement of illustrations affects all dimensions, and that arrangement of material should be such that awkward proportions are avoided and no loss of clarity results.

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